AME

# AME5144

# High Efficiency, 37V Step-Up Converter for 2 to 10 White LEDs

## ■ General Description

The AME5144 is an efficient driver for up to ten white LED applications. They are ideal for large LCD backlight displays in Cell Phone, PDAs, and other handheld devices. The AME5144 is switch-mode boost converter with constant LED current, rather than output voltage. The series connection allows the LED currents to be identical for uniform brightness and minimizes the number of trace to the LEDs. The AME5144 drives series-connected LEDs to controlled-current pin which connected a typically 13Ω sense resistor, not an expensive fraction-ohm value.

Fast 1MHz current-mode PWM operation allows for small input and output capacitors and a small inductor while minimizing ripple on the input supply/battery. Soft-start eliminates inrush current during startup. To control LED brightness, the LED current can be pulsed by applying a single analog/PWM signal with a frequency range from 200Hz to 30KHz for the control pin CTRL.

The AME5144 is available in space saving, 8 pin, 3mm x 3mm x 0.75mm DFN package.

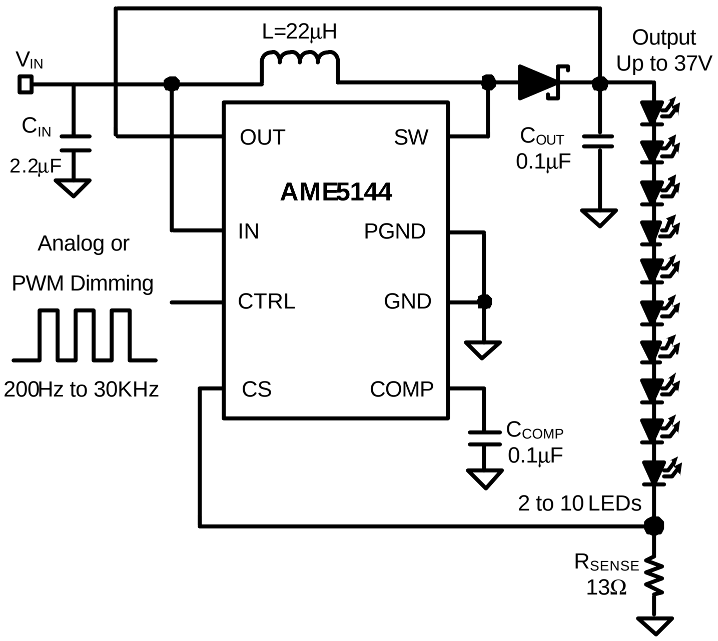
## ■ Features

- Up to 10 LEDs at 25mA
- 86% Efficiency
- 1.7% Current-Regulation Accuracy
- Output Overvoltage Protection
- Flexible Dimming Control
  - Analog
  - Direct-PWM Internal Filter
- 1MHz PWM Switching Frequency
- 0.1uF Output Capacitor
- Soft-Start Eliminates Inrush Current
- 2.6V to 5.5V Input Range
- 0.3uA Shutdown current
- DFN 3mm x 3mm x 0.75mm Package with Exposed Paddle
- All AME's Lead Free Products Meet RoHS Standards

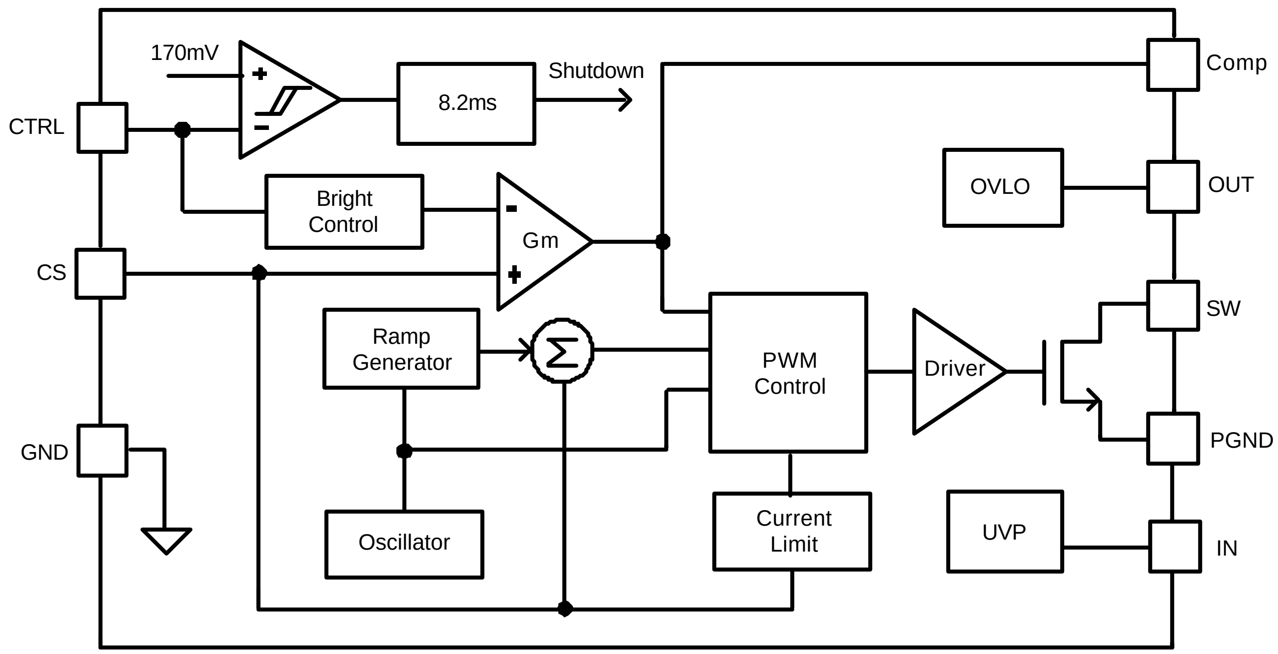
## ■ Applications

- Cell Phones and Smart Phones
- PDAs, Palmtops, and Wireless Handhelds
- e-Books and Subnotebooks
- White LED Display Backlighting

## ■ Typical Application

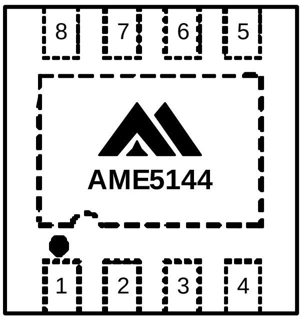



## ■ Function Block Diagram



## ■ Pin Configuration

**DFN-8C**
**(3mmx3mmx0.75mm)**
**Top View**




**AME5144-AVAxxx**

1. OUT
2. IN
3. CTRL
4. CS
5. COMP
6. GND
7. PGND
8. SW

*** Die Attach:**
**Conductive Epoxy**

## ■ Pin Description

| Pin Number | Pin Name | Pin Description |
|---|---|---|
| 1 | OUT | Overvoltage Sense. When OUT is greater than 38.5V(Typ.), the internal n-channel MOSFET turns off until OUT drops below 37V(Min), then the IC reenters soft-start Connect a 0.1uf ceramic capacitor from OUT to ground. In shutdown, $V_{OUT}$ is one diode drop below $V_{IN}$. |
| 2 | IN | Input Voltage Supply. The input voltage range is 2.6V to 5.5V. Connect a 2.2uF ceramic capacitor from IN to GND. |
| 3 | CTRL | Brightness Control pin. Either an Analog or PWM control signal can be used. The PWM signal must be between 200Hz and 30KHz. Varying the voltage from +0.24V to +1.65V adjusts the brightness from dim to 100% brightness, respectively. Any voltage above +1.65V does not increase brightness. Hold CTRL below 100mV to shut down the IC after an 8.2ms delay. |
| 4 | CS | Current Sense Feedback input. Connect a resistor from CS to GND to set the LED bias current. The voltage at CS regulates to $V_{CRTL}$/5 or 0.330V. |
| 5 | COMP | Compensation input. Connect a 0.1µF Ceramic Capacitor(Ccomp) from COMP to GND. $C_{comp}$ stabilizes the converter, controls soft-start and lowpass filters direct PWM dimming at CTRL. Ccomp discharges to 0V through an internal 20KΩ resistor in showdown. |
| 6 | GND | Ground. Connect to PGND and exposed pad directly under the IC. |
| 7 | PGND | Power Ground. Connect to PGND and exposed pad directly under the IC. |
| 8 | SW | Inductor Connection. Connect SW to the node between the inductor and schottky diode. SW is high impedance in shutdown. |

## ■ Ordering Information

**AME5144 - x x x xxx**

- xxx — Output Voltage
- x (third) — Number of Pins
- x (second) — Package Type
- x (first) — Pin Configuration & Special Feature

| Pin Configuration & Special Feature | | Package Type | Number of Pins | Output Voltage |
|---|---|---|---|---|
| A (DFN-8C) | 1. OUT<br>2. IN<br>3. CTRL<br>4. CS<br>5. COMP<br>6. GND<br>7. PGND<br>8. SW | V: DFN | A: 8 | ADJ: Adjustable |

## ■ Available Options

| Part Number | Marking* | Output Voltage | Package | Operating Ambient Temperature Range |
|---|---|---|---|---|
| AME5144-AVAADJ | A5144<br>AMYMXX | ADJ | DFN-8C | -40$^{O}$C to +85$^{O}$C |

Note:
1. The first 2 places represent product code. It is assigned by AME such as AM.
2. Y is year code and is the last number of a year. Such as the year code of 2008 is 8.
3. A bar on top of first letter represents Green Part such as $\overline{A}$5144.
4. The last 3 places MXX represent Marking Code. It contains M as date code in "month", XX as LN code and that is for AME internal use only. Please refer to date code rule section for detail information.
5. Please consult AME sales office or authorized Rep./Distributor for the availability of output voltage and package type.

## Absolute Maximum Ratings

| Parameter | Maximum | Unit |
|---|---|---|
| $V_{IN}$, to GND | -0.3 to 6.0 | V |
| CTRL, CS, COMP, to GND | -0.3 to ($V_{IN}$ + 0.3) | V |
| SW, OUT to GND | -0.3 to 40 | V |
| PGND to GND | -0.3 to 0.3 | V |
| ESD Classification | B* | |

Caution: Stress above the listed absolute maximum rating may cause permanent damage to the device.
* HBM B: 2000V ~ 3999V

## Recommended Operating Conditions

| Parameter | Rating | Unit |
|---|---|---|
| Storage Temperature Range | -65 to +150 | $^oC$ |
| Ambient Temperature Range | -40 to +85 | $^oC$ |
| Junction Temperature Range | -40 to +125 | $^oC$ |

## Thermal Information

| Parameter | Package | Die Attach | Symbol | Maximum | Unit |
|---|---|---|---|---|---|
| Thermal Resistance* (Junction to Case) | DFN-8C | Conductive Epoxy | $\theta_{JC}$ | 17 | $^oC$ / W |
| Thermal Resistance (Junction to Ambient) | | | $\theta_{JA}$ | 125 | $^oC$ / W |
| Internal Power Dissipation | | | $P_D$ | 800 | mW |
| Solder Iron (10 Sec)** | | | | 350 | $^oC$ |

* Measure $\theta_{JC}$ on backside center of molding compund if IC has no tab.
** MIL-STD-202G 210F

## ■ Electrical Specifications

$V_{IN}$ = 3V, L=22µH, $C_{IN}$=2.2µF, $C_{OUT}$=0.1µF, $C_{COMP}$=0.1µF, $R_{SENSE}$ =13Ω, $T_A$ = 25ºC, unless otherwise noted.

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Input voltage | $V_{IN}$ | | 2.6 | | 5.5 | V |
| Adjustable Output Range | $V_{OUT}$ | Note 1 | $V_{IN}$-VD | | 37 | V |
| Input Undervoltage Locked | UVP | Rising edge | 2.10 | 2.38 | 2.55 | V |
| Input Undervoltage Locked Hysteresis | UVP Hysteresis | | | 30 | | mV |
| Quiescent Current | $I_Q$ | No Switching, $V_{CS}$=0.5V | | 0.5 | 0.7 | mA |
| Shutdown Current | $I_{SHDN}$ | CTRL=GND, $V_{OUT}$=$V_{IN}$ | | 0.3 | 2 | µA |
| Over Voltage Protection | OVP | $V_{OUT}$ Rising | 37 | 38.5 | 40 | V |
| Over Voltage Protection Hysteresis | $OVP,_{HYST}$ | | | 2 | | V |
| OUT Input Bias Current | $I_{B,OUT}$ | $V_{OUT}$=32V, $V_{CTRL}$>0.24V | 9 | 20 | 35 | µA |
| | | OUT=IN, CTRL=GND | | 0.01 | 1 | |
| CTRL to CS Regulation | $V_{CS}$ | $V_{CTRL}$=1.5V, $V_{IN}$=2.6V to 5.5V | 0.290 | 0.300 | 0.310 | V |
| CS Input Bias Current | $I_{CS}$ | $V_{CS}$=$V_{CTRL}$/5 | | 0.01 | 1 | µA |
| CS Maximum Brightness Clamp Voltage | $V_{CS(MAX)}$ | $V_{CTRL}$=3V | 310 | 330 | 347 | mV |
| CTRL Voltage for CS Maximum Brightness Clamp | $V_{CTRL(MAX)}$ | | | 1.65 | | V |
| CTRL Input Resistance | $R_{CTRL}$ | $V_{CTRL}$<=1.5V | 250 | 500 | 780 | KΩ |
| CTRL Dual-Mode Threshold | $V_{DM}$ | | 100 | 170 | 240 | mV |
| CTRL Dual-Mode Hysteresis | $V_{DM}$ Hysteresis | | | 5 | | mV |
| CTRL Shutdown Enable Delay | | Note 2 | 6.0 | 8.2 | 10.5 | mS |

## ■ Electrical Specifications (contd.)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| CS to Comp Transconductance | Gm | $V_{COMP}$=1.5V | 32 | 50 | 82 | µS |
| COMP Input Resistance to Ground | | In shutdown, UVLO or OVLO | | 20 | | KΩ |
| Switch Frequency | $f_{OSC}$ | | 0.75 | 1.0 | 1.25 | MHz |
| Minimum Duty Cycle | $D_{MIN}$ | PWM Mode | | 12 | | % |
| | | Pulse Skipping | | 0 | | |
| Maximum Duty Cycle | $D_{MAX}$ | CTRL=IN, CS=GND | 94 | 95 | | % |
| Switch On-Resistance | $R_{DS,ON}$ | $I_{SW}$=190mA | | 0.8 | 1.35 | Ω |
| Switch Leakage Current | $I_{SW,LK}$ | $V_{SW}$=37V, CTRL=GND | | 0.01 | 5 | µA |
| Switch Current Limit | $I_{SW,CL}$ | Duty Cycle=90% | 500 | 700 | 900 | mA |

Note 1: VD is the forward-voltage drop of the Schottky diode in Typical Application.
Note 2: Time from CTRL going below the Dual-Mode threshold to IC shutdown.

## ■ Detailed Description

The high efficiency and small size of the AME5144 make them ideally suited to driver up to ten series-connected LEDs. They operate as a boost DC-DC converter that controls output current rather than voltage. A low 300mV current-sense threshold minimized the losses. The AME5144 provide even illumination by sourcing the same output current through each LED, eliminating the need for expensive factory calibration. The fast 1MHz internal oscillator allows for small inductor and small input and output capacitors while minimizing input and output ripple.

The single analog control input (CTRL) allows easy adjustment of LED brightness and on/off control. This allows simple logic-level on/off control, analog voltage control, or PWM duty-cycle control of both brightness and shutdown. In shutdown, supply current is reduced to a low 0.3µA (Typ.). A soft-start gradually illuminates the LEDs, eliminating the inrush current during startup.

### Shutdown

The AME5144 enter shutdown when VCTRL is less than 100mV for more than 8.2ms. When shutdown, the supply current is reduced to 0.3µA (Typ.) approximately.

The 0.3uA supply current is applied for the voltage-detection circuitry. $C_{COMP}$ is discharge during shutdown, allowing the device to reinitiate soft-start when enabled. Although the internal n-channel MOSFET does not switch in shutdown, there is still a DC current path between the input and the LEDs through the inductor and Schottky diode. The minimum forward voltage of the LED array must exceed the maximum input voltage to ensure that the LEDs remain off in shutdown. However, with two or more LEDs, the forward voltage is enough to keep leakage current low, less than 1µA (Typ.).

### Soft-Start

The AME5144 attain soft-start by charging $C_{COMP}$ gradually with a current source. When $V_{COMP}$ rises above 1.25V, the internal MOSFET begins switching at a reduced duty cycle. When $V_{COMP}$ rises above 2.25V, the duty cycle is at its maximum. See the Typical Operation Characteristics for an example of soft-start operation.

### Over Voltage Protection

OVP is designed to prevent the output voltage from exceeding the maximum switch voltage rating of 38.5V (Typ.). The protection circuitry stops the internal MOSFET from switching. There is a 1.5V hysteresis associated with this circuitry which will cause the output to fluctuate between 38.5V and 37V.

### Adjusting LED Current

Adjusting the output current of the AME5144 changes the brightness of the LEDs. An analog input (CTRL) and the sense-resistor values set the output current. Output current is given by:

$I_{LED}=V_{CTRL}/(5xR_{SENSE})$

The $V_{CTRL}$ voltage range for adjusting output current is 0.24V to 1.65V. To set maximum current, calculate RSENSE when VCTRL is at its maximum as follows:

$R_{SENSE}=1.65V / (5 \times I_{LED})$

Power dissipation in $R_{SENSE}$ is typical less than 10mW, allowing the use of small surface-mount resistor.

### PWM Dimming Control

A. Using DC Signal for CTRL Pin

For CTRL, applying a DC signal in the range of 0.24V to 1.65V control the LED current. CTRL can be overdriven; however, applying a CTRL greater than 1.65V does not increased the LED current above the level at 1.65V.

B. Using PWM signal for CTRL pin

The CTRL input is used as a digital input allowing LED brightness control with a logic-level PWM signal applied directly to CTRL. The frequency range is from 200Hz to 30KHz, while 0% duty cycle corresponds to minimum current, and 100% duty cycle corresponds to full current.

The error amplifier and compensation capacitor form a low pass filter so PWM dimming results in DC current to the LEDs without the need for any additional RC filters.

### Capacitor Selection

Ceramic capacitors with X5R, X7R, or better dielectric are recommended for stable operation over the entire operating temperature range. The exact values of input and output capacitors are not critical. The typical value for input capacitor is 2.2µF, and the typical value for output capacitor is 0.1µF. Higher values capacitors can be used to reduce input and output ripple, but at the expense of size and higher cost. $C_{COMP}$ stabilizes the converter and control soft-start. Connect a 0.1µF capacitor from COMP to GND.

### Inductor Selection

Inductor values range from 10µH to 47µH. A 22µH inductor optimizes the efficiency for most applications while maintaining low 12mVp-p input ripple. Inductor with low DCR can be more efficiency. To prevent core saturation, ensure that the inductor-saturation current rating exceeds the peak inductor current for the application. Calculate the peak inductor current with the following formula:

$$I_{PEAK} = \frac{V_{OUT(MAX)} \times I_{LED(MAX)}}{0.9 \times V_{IN(MIN)}} + \frac{V_{IN(MIN)} \times 0.9us}{2 \times L}$$

22µH, 250mA inductor Murata LQH32CN220K and Sumida CDRH5D16NP- 220MB are recommended.

### Schottky Diode Selection

The high switching frequency of the AME5144 demands a high-speed rectification diode (D1) for optimum efficiency. A Schottky diode is recommended due to its fast recovery time and low forward-voltage drop. Ensure that the diode's average and peak current rating exceed the average output current and peak inductor current. In addition, the diode's reverse breakdown voltage must exceed $V_{OUT}$. The RMS diode current can be approximated from:

$$I_{DIODE(RMS)} = \sqrt{I_{OUT} \times I_{PEAK}}$$

200mA, 40V Schottky diode SOD-523 or Central Semiconductor CMOSH-4E are recommended for applications.

### Layout Consideration

Due to fast switching waveforms and high-current paths, careful PC board layout is required. When laying out a board, minimum trace lengths between the IC and $R_{SENSE}$, the inductor, the diode, the input capacitor and output capacitor. Keep trace short and wide. Keep noisy traces, such as the SW node trace, away from CS.

The input bypass capacitor $C_{IN}$ should be placed as close to the IC as possible. This will reduce copper trace resistance, which effect the input voltage ripple of the IC. The output capacitor, $C_{OUT}$, should also be placed close to the IC and connected directly between the OUT and GND pins. PGND and GND should be connected directly to the exposed paddle underneath the IC. The ground connections of $C_{IN}$ and $C_{OUT}$ should be as close together as possible. Any copper trace connections with the $C_{OUT}$ capacitor can increase the series resistance which directly effects output ripple and efficiency. The current setting resistor, $R_{SENSE}$, should be kept close to the CS pin to minimize copper trace connections that can inject noise in to the system. The traces from IN to the inductor and from Schottky diode to the LEDs can be longer.

**Duty Cycle**

The maximum duty cycle of the switching regulator determines the maximum boost ratio of output-to-input voltage that the converter can attain in mode of operation. The duty cycle for a given boost application is defined as: This applies for continuous mode operation.

$$D = \frac{V_{OUT} + V_{DIODE} - V_{IN}}{V_{OUT} + V_{DIODE} - V_{SW}}$$

**Calculating Load Current**

The load current is related to the average inductor current by the relation:

$I_{LOAD} = I_{IND}(AVG) \times (1 - D)$

Where " D" is the duty cycle of the application. The switch current can be found by:

$I_{SW} = I_{IND}(AVG) + 1/2 (I_{RIPPLE})$

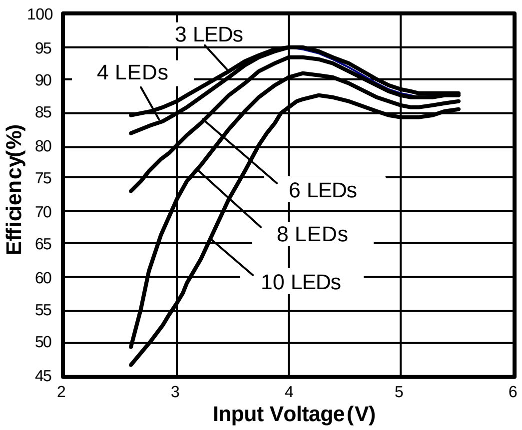
Inductor ripple current is dependent on inductance, duty cycle, input voltage and frequency:

$I_{RIPPLE} = D \times (V_{IN} - V_{SW}) / (f \times L)$

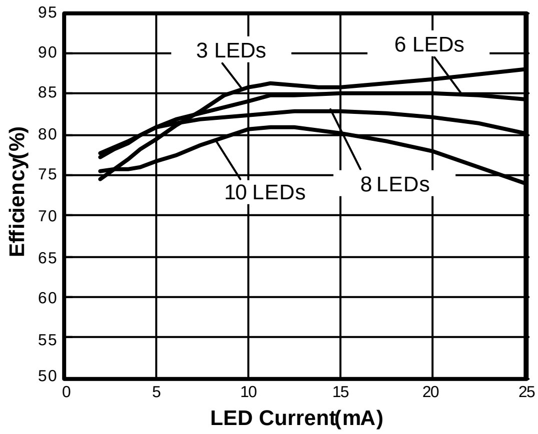
Combining all terms, we can develop an expression which allows the maximum available load current to be calculated:

$$I_{LOAD} = (1-D) \times \left( I_{SW}(max) - \frac{D(V_{IN} - V_{SW})}{2fL} \right)$$

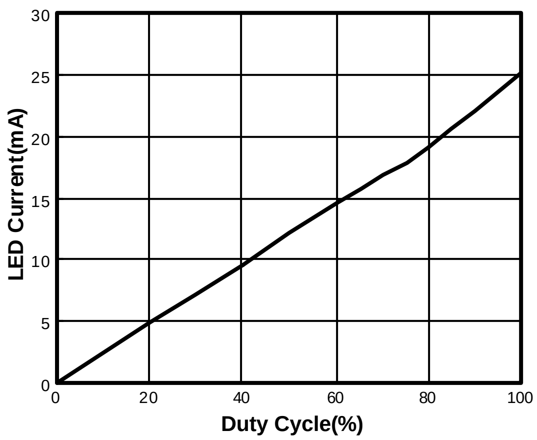
**Efficiency vs Input Voltage**



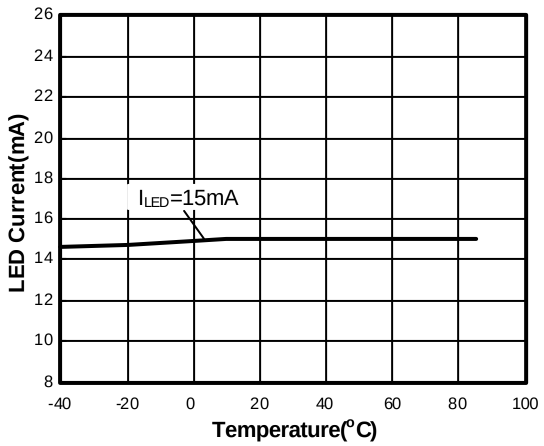

**Efficiency vs LED Current**



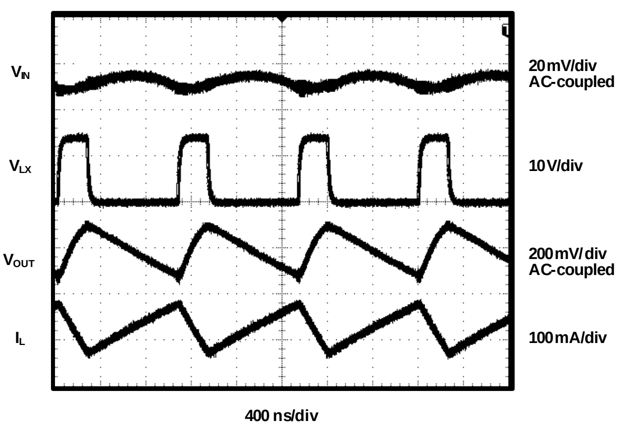

**LED Current vs Direct-PWM Dimming**



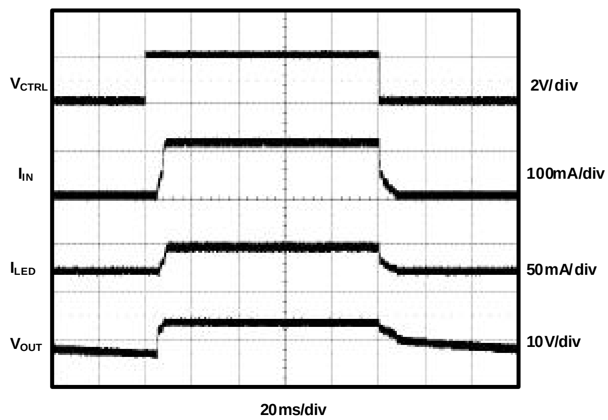

**LED Current vs Ambient Temperature**



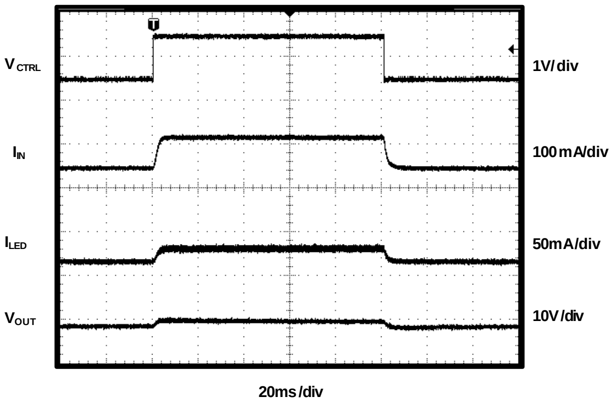

**Switching Waveforms**



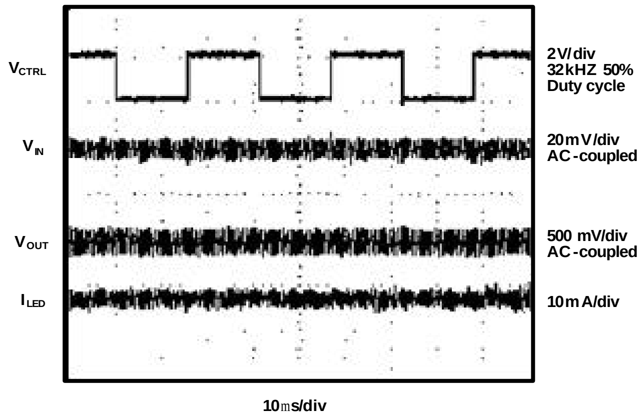

**Soft-Start And Shutdown Response**



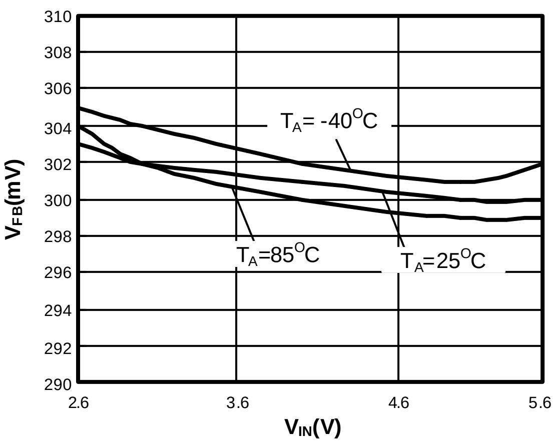
**Ctrl Step Response**




**Direct-PWM Dimming Response**




**$V_{FB}$ vs $V_{IN}$**

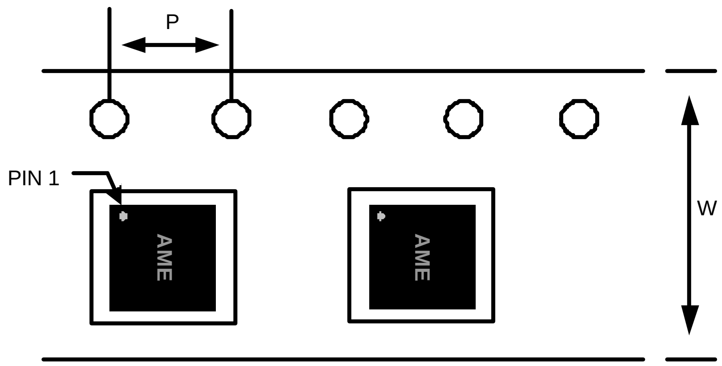


## ■ Date Code Rule

| Month Code | |
|---|---|
| 1: January | 7: July |
| 2: February | 8: August |
| 3: March | 9: September |
| 4: April | A: October |
| 5: May | B: November |
| 6: June | C: December |

## ■ Tape and Reel Dimension

**DFN-8C**
**(3mmx3mmx0.75mm)**

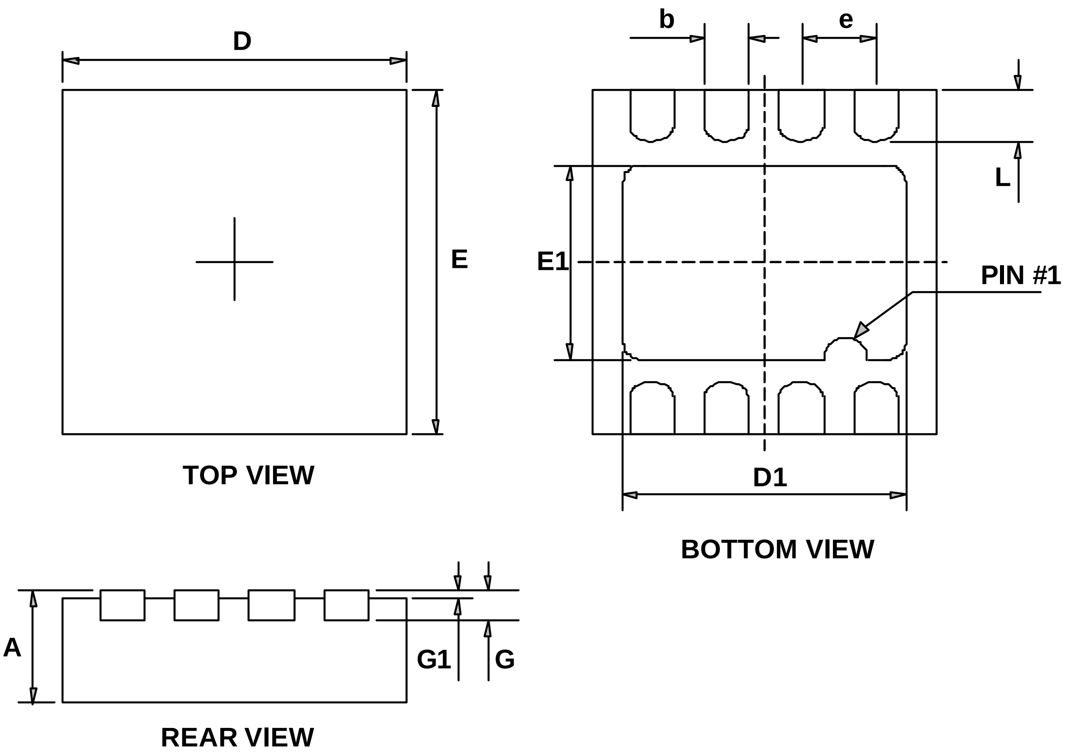



**Carrier Tape, Number of Components Per Reel and Reel Size**

| Package | Carrier Width (W) | Pitch (P) | Part Per Full Reel | Reel Size |
|---|---|---|---|---|
| DFN-8C (3x3x0.75mm) | 12.0±0.1 mm | 4.0±0.1 mm | 3000pcs | 330±1 mm |

## ■ Package Dimension

**DFN-8C (3mmx3mmx0.75mm)**




| SYMBOLS | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 0.700 | 0.800 | 0.028 | 0.031 |
| D | 2.900 | 3.100 | 0.114 | 0.122 |
| E | 2.900 | 3.100 | 0.114 | 0.122 |
| e | 0.600 | 0.700 | 0.024 | 0.028 |
| D1 | 2.200 | 2.400 | 0.087 | 0.094 |
| E1 | 1.400 | 1.600 | 0.055 | 0.063 |
| b | 0.200 | 0.320 | 0.008 | 0.013 |
| L | 0.375 | 0.575 | 0.015 | 0.023 |
| G | 0.153 | 0.253 | 0.0060 | 0.010 |
| G1 | 0.000 | 0.050 | 0.0000 | 0.002 |

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