

## Design Consideration with AP3036/A

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### 1. Introduction

The AP3036/A is a boost DC-DC converter which uses current mode control scheme to provide excellent line and load regulation. Operation can be best understood by referring to the Figure 2.

The AP3036/A is an inductor-based DC/DC converter designed to drive up to eight white LEDs in series for backlight. Only one feedback resistor is needed to control the LED current and obtain required brightness.

A constant frequency 1.0MHz PWM control scheme is employed in this IC, which means tiny external components can be used. Specifically, 1mm tall inductor and 0.22 $\mu$ F output capacitor for a typical application is sufficient. Additionally, the Schottky diode in boost circuit is integrated on this chip. AP3036/A also provides a disable pin to ease its use for different systems.

The output over-voltage protection is implemented in AP3036/A. When any LED is broken or in other

abnormal conditions, the output voltage will be clamped.

The AP3036/A is available in standard SOT-23-6 and TSOT-23-6 packages.

### 2. Function Block Description

The pin configuration and the representative block diagram of the AP3036/A are respectively shown in Figure 1 and Figure 2.

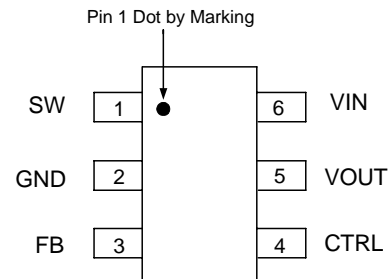


Figure 1. Pin Configuration of AP3036/A (Top View)

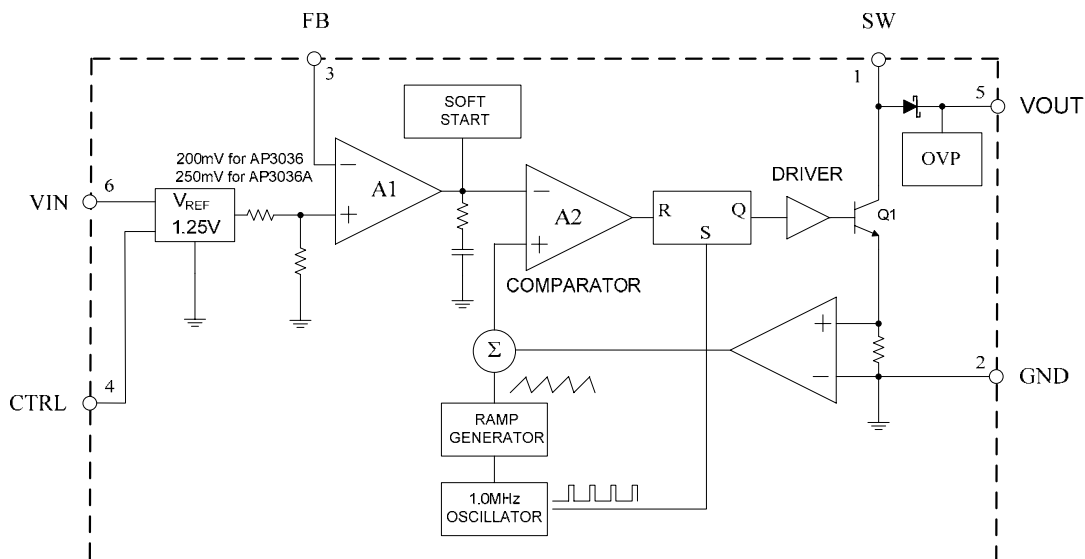


Figure 2. Functional Block Diagram of AP3036/A

### 3. Operation

The AP3036/A uses a constant frequency, current mode control scheme to provide excellent line and load regulation. Operation can be best understood by referring to Figure 2 and Figure 3. Every switching cycle can be divided into two time subintervals

At the start of each switching cycle, the oscillator will set the logic control, which turns on the power switch Q1. Then the inductor current will increase linearly. The voltage, proportional to the inductor current and sampled by the sense resistor, is added with oscillator ramp voltage and the resulting voltage is fed into the non-inversion input of comparator A2. When this voltage exceeds the level at the inversion input of A2, the output of A2 is changed and the logic control is reset to turn off the switch. In this time interval, the white LED current is provided by the output capacitor. The output voltage drops slightly.

After the switch turns off, the inductor provides current to the white LEDs and charges the output

capacitor. Due to negative voltage applied to the inductor current decreases linearly. The switch will not turn on until the oscillator set logic control again. The oscillator frequency is set at 1MHz.

It is clear that the voltage level at the inversion input of A2 sets the peak current level to keep the output in regulation. This voltage level is the output signal of error amplifier A1, and is the amplified signal of difference between feedback voltage and reference voltage of 200mV or 250mV. So, constant output current can be provided by this operation mode.

### 4. Application

In Figure 3, the inductor L, the built-in switch and Schottky diodes build a typical boost converter.  $C_{IN}$  and  $C_{OUT}$  are the input and output capacitor respectively. The white LEDs act as the load.  $10\Omega$  resistor is the feedback resistor, which determines the LEDs' current. In this application, the CTRL pin should be connected to a high level voltage to enable the circuit or a low level voltage to disable the circuit. It should not be floating.

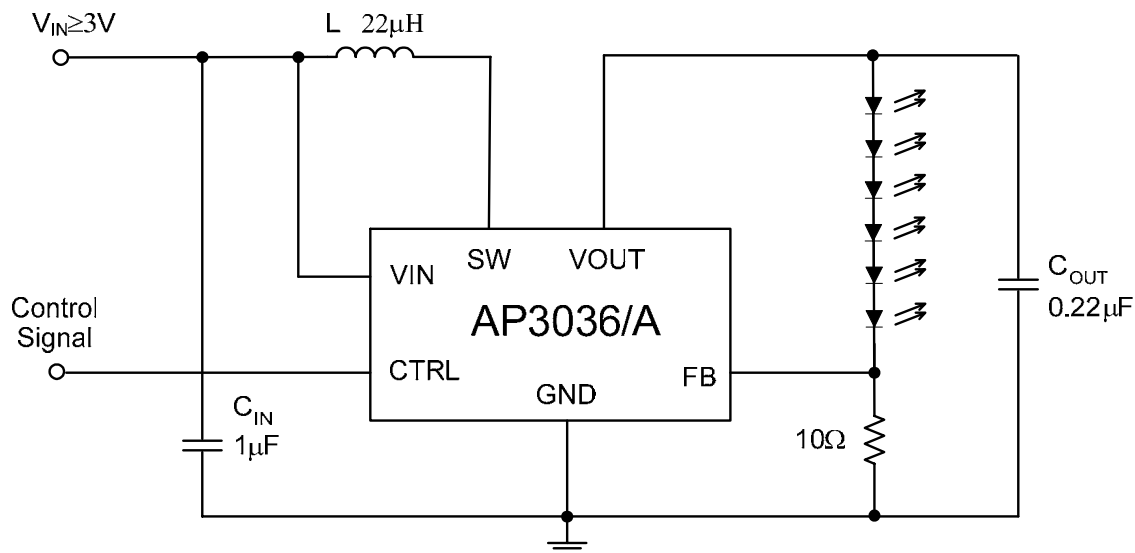


Figure 3. Typical Application of AP3036/A

## 5. Components selection

### 5.1 Induct Selection

To obtain stable output current and greater output current capability, the 22 $\mu$ H inductor is recommended. Small size and better efficiency are the major concerns for portable device, such as AP3036/A used for mobile phone. The inductor should have low core loss at 1.0MHz and low DCR. CDRH5D16NP-220NC provided by Sumida is a good choice.

### 5.2 Capacitor Selection

The small size of ceramic capacitors makes them ideal for this application. Compared with other types of capacitors, X7R and X5R types feature wider voltage and temperature ranges. So, ceramic capacitors such as those provided by Murata are recommended. Considering that the operation frequency is 1.0MHz, the 1 $\mu$ F input capacitor and 0.22 $\mu$ F output capacitor are acceptable.

### 5.3 Resistor Selection

In order to obtain an accurate LED current, a high precision resistor is needed.

## 6. Application Hints

### 6.1 LED Current Control

Refer to Figure 3, the LED current is controlled by the feedback resistor. LED's current accuracy is determined by the regulator's feedback threshold accuracy and is independent of the LED's forward voltage variation. So the precise resistors are preferred. The resistance of  $R_{ISET}$  is in inverse proportion to the LED current since the feedback reference is fixed at 200mV for AP3036 (250mV for AP3036A). The relation with  $R_{ISET}$  and LED current ( $I_{LED}$ ) can be expressed as below:

$$R_{ISET} = \frac{200mV}{I_{LED}}$$

### 6.2 Over Voltage Protection

The AP3036/A has an internal open-load protection circuit. When the LEDs are disconnected from circuit or fail open, the output voltage is clamped at 30V. The AP3036/A will switch at a low frequency, and minimize current to avoid input voltage drop.

### 6.3 Soft Start

The AP3036/A has an internal soft start circuit to limit the inrush current during startup. If logic low time on CTRL pin is more than about 0.7ms and then enable the IC, the AP3036/A will start smoothly to

protect system departments. The time of startup is controlled by internal soft start capacitor.

### 6.4 Standby and Dimming

To avoid audio noise and achieve high frequency dimming, the AP3036/A involves a standby function. If logic low time on CTRL pin is less than about 0.7ms and then enable the IC, the AP3036/A will hold on standby mode and start directly to achieve high frequency dimming. Details please refer to Figure 5.

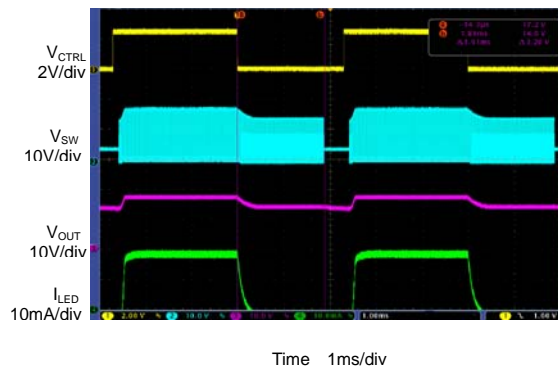


Figure 5. Standby Waveform

#### 6.4.1 Adding a Control Signal to CTRL Pin

For controlling the LED brightness, the AP3036/A can perform the dimming control by applying a PWM signal to CTRL pin. The internal soft start and the wide range dimming frequency from 100Hz to 100kHz can eliminate inrush current and audio noise when dimming. The average LED current is proportional to the PWM signal duty cycle. The magnitude of the PWM signal should be higher than the maximum enable voltage of CTRL pin, in order to let the dimming control perform correctly.

Adding a PWM signal to CTRL pin directly, the AP3036/A is turned on and off by this signal. When the PWM frequency is lower than 2.5kHz (Typ.), the IC works in the soft start mode to dim the light. But we intensely suggest setting the PWM signal frequency higher than 2.5 kHz to avoid audio noise. In this situation, the IC works in the standby mode and start directly to achieve dimming the light. More details please refer to Figure 6 and Figure 7.

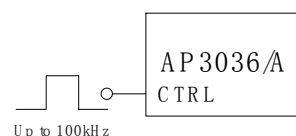


Figure 6. Dimming Control under PWM Signal

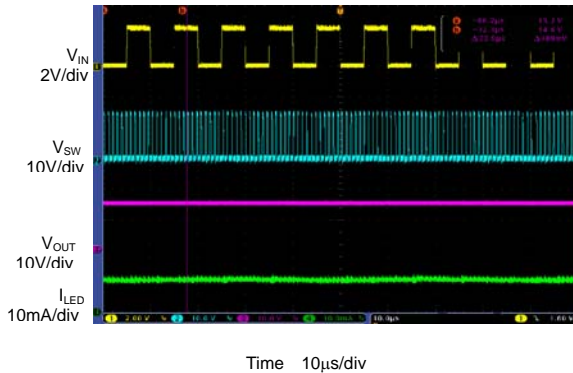


Figure 7. High Frequency Dimming Waveform (100kHz)

#### 6.4.2 Changing the Effective Feedback Voltage

There are two popular methods to change the effective feedback voltage.

First, adding a constant DC voltage through a resistor divider to FB pin can control the dimming. Changing the DC voltage or resistor between the FB pin and the DC voltage can get appropriate luminous intensity. Comparing with all kinds of PWM signal control, this method features a stable output voltage and LEDs current. Please refer to Figure 8.

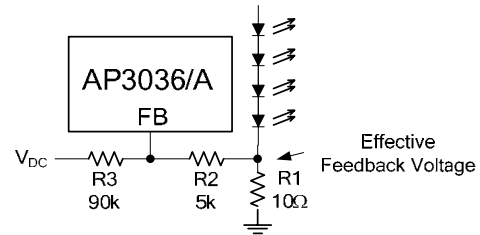


Figure 8. Dimming Control under DC Voltage

Second, using a filtered PWM signal can do it. The filtered PWM signal can be considered as a varying and adjustable DC voltage. Please refer to Figure 9.

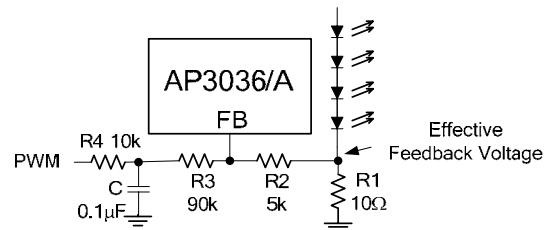


Figure 9. Dimming Control under Filtered PWM Voltage