Design Consideration with AP3033

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1. Introduction
The AP3033 is an inductor-based DC/DC boost converter designed to drive LED arrays. The 1.3A switching current allows AP3033 to be used for different LCD panel backlights, from 7' to 10' ((3S8P LED arrays typically). The output current accuracy is determined by the feedback voltage and resistor RSET.

To save space and lower the cost, AP3033 is designed to operate at 1MHz frequency, which enables tiny periphery components to be used, such as, a 10µH inductor with height of 1mm for typical applications can be used.

An OVP circuit is integrated in this chip, which protects the IC under open load condition. It employs UVLO, soft-start, current limiting and OTSD to protect the circuit.

A control terminal is designed to turn on or turn off the device, to achieve a better flexible maneuverability. In practice, adding a PWM signal on this terminal to control the luminous intensity is a good idea. The main application fields of the AP3033 consist of 7' to 10' LCD Panels, Digital Photo GPS Receiver, EPC, PDVD, etc. As is well known, the main feature of these handheld devices is compactness. To satisfy the requirements for small mounting space constraints, this IC is available in small TSOT-23-6 package to save space.

2. Functional Block Description
The pin configuration and the Function Block Diagram of the AP3033 are respectively shown in Figure 1 and Figure 2.

![Figure 1. Pin Configuration of AP3033 (Top View)](image)

![Figure 2. Functional Block Diagram of AP3033](image)
3. Operation
The AP3033 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, 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. So, constant output current can be provided by this operation mode.

The device will enter a pulse skipping state at light load to lower the loss. In fact, as the current through LEDs reduces, the device will begin skipping pulses. At this state, the device operates at a low frequency and discontinuous current mode (DCM). One feature of the DCM is that the SW pin exhibits ringing due to the LC tank circuit formed by the inductor in combination with the switch and diode capacitance after the current through the inductor goes back to zero. It is necessary to point out that the skipping pulse will cause a low frequency ripple on the output.

4. Typical Application
In Figure 3, the inductor L, the schottky diode and the built-in switch build a typical boost converter. C_IN and C_OUT are the input and output capacitor respectively. The white LEDs act as the load. R_SET 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.
5. Components Selection

Inductor Selection
To obtain stable output current and greater output current capability, a 10µH inductor is recommended. The inductor should have low core loss and low DCR at 1.0MHz. CDRH5D28RHPNP-100M provided by Sumida is a good choice.

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 10µF input capacitor and 10µF output capacitor are acceptable.

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

6. Application Hints

LED Current Control
Refer to Figure 3, the LED current is controlled by the feedback resistor R_{ISET}. LEDs' current accuracy is determined by the feedback voltage and resistor R_{ISET}, 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. The relation for R_{ISET} and LED current (I_{LED}) can be expressed as below:

\[ R_{ISET} = \frac{200mV}{I_{LED}} \]

Over Voltage Protection
The AP3033 has an internal open load protection circuit. When the LEDs are disconnected from circuit, the output voltage is clamped at about 17V. The AP3033 will switch at a low frequency, and minimize current to avoid input voltage drop.

Soft Start
The AP3033 has an internal soft start circuit to limit the inrush current during startup. If logic low time on CTRL pin is more than 0.45ms and then enable the IC, AP3033 will start smoothly to protect the power supplier. The time of startup is controlled by internal soft start capacitor. Details please refer to Figure 4.

Dimming
To control the LED brightness, AP3033 provides typically 200mV feedback voltage when the CTRL pin is constantly pulled high. However, CTRL pin allows a PWM signal to reduce this regulation voltage by changing the PWM duty cycle to implement LED brightness dimming control. Detail circuit is shown in Figure 5. The relationship between the duty cycle and LED current can be expressed as below

\[ I_{LED} = \frac{200mV \times D_{PWM}}{R_{ISET}} \]

Where
\( D_{PWM} = \) duty cycle of the PWM signal
\( 200mV = \) internal reference voltage

Two other typical types of dimming control circuit are present as below:

(1) Using DC voltage to change the Effective Feedback Voltage
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 6.
Figure 6. Dimming Control Using DC Voltage

(2) Using filtered PWM signal to change the Effective Feedback Voltage

The filtered PWM signal can be considered as a varying and adjustable DC voltage. Please refer to Figure 7.

Figure 7. Dimming Control Using Filtered PWM Voltage