

Design Consideration with AP3031

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1. Introduction

The AP3031 is an inductor-based DC/DC boost converter designed to drive LED arrays. 1.4A switching current allows AP3031 to be used in different 7' to 10' LCD panel backlights (3*13 LED arrays typically). The output current accuracy is determined by the feedback voltage and resistor R_{ISET} .

To save space and reduce cost, this AP3031 operates at 1MHz normally, which means that the tiny periphery components are acceptable. In fact, 1mm tall 4.7 μ H inductor and 0.47 μ F output capacitors for typical applications are very appropriate.

An OVP circuit is integrated in this chip, which protects the IC under open load condition. The AP3031 includes UVLO, soft-start, current limit and OTSD to protect the circuit.

To achieve flexible maneuverability, a control terminal is designed to turn on or turn off this device. In practice, adding a PWM signal on this terminal to control the luminous intensity is a good idea. The main application field of the AP3031 consists of 7' to

10' LCD panels, including digital photo frame, 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 SOT-23-6, TSOT-23-6 and SOIC-8 packages to save space.

2. Functional Block Description

The pin configuration and the representative block diagram of the AP3031 are respectively shown in Figure 1 and Figure 2.

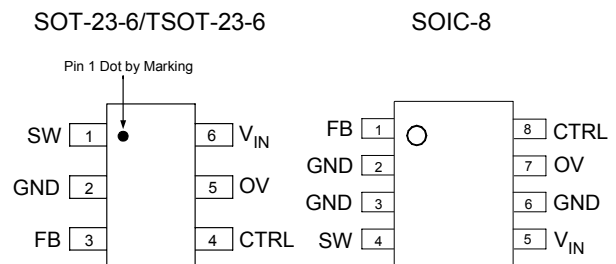


Figure 1. Pin Configuration of AP3031 (Top View)

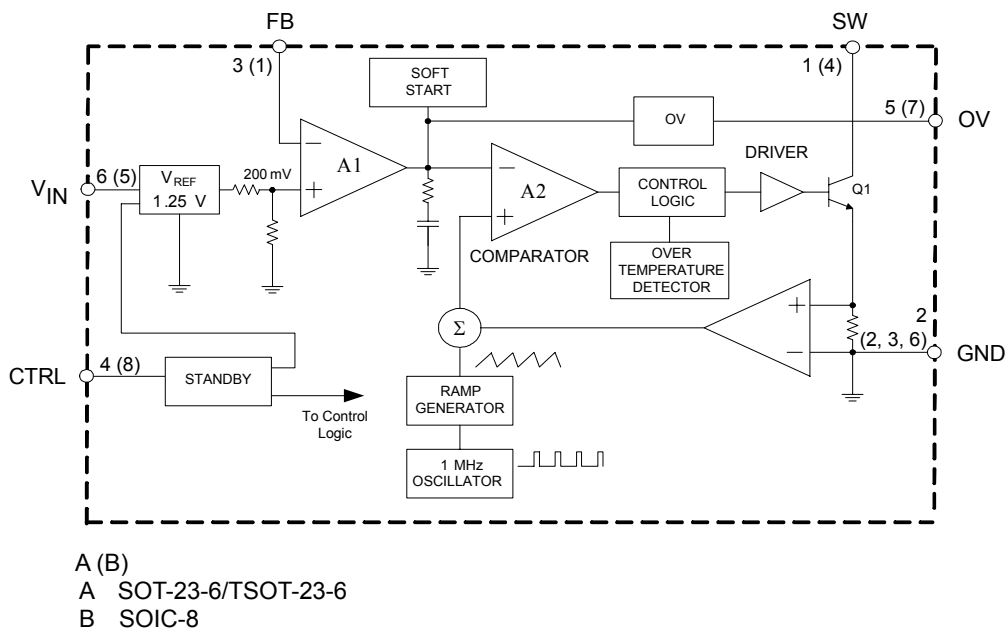


Figure 2. Functional Block Diagram of AP3031

3. Operation

The AP3031 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. C1 and C2 are the input and output capacitor respectively. The white LEDs act as the load. R_{ISSET} 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.

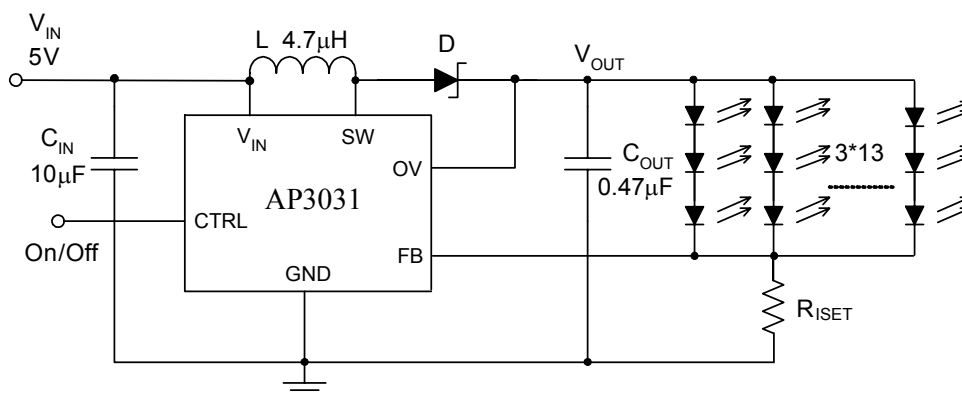


Figure 3. Typical Application of AP3031 (3×13 WLEDs)

5. Components Selection

Inductor Selection

To obtain stable output current and greater output current capability, the 4.7μH inductor is recommended. The inductor should have low core loss at 1.0MHz and low DCR. CDRH5D16NP-4R7NC 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 0.47μF 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 AP3031 has an internal open load protection circuit. When the LEDs are disconnected from circuit or fail open, the output voltage is clamped at about 17V. The AP3031 will switch at a low frequency, and minimize current to avoid input voltage drop.

Soft Start

The AP3031 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, AP3031 will start smoothly to protect the supplier. The time of startup is controlled by internal soft start capacitor. Details please refer to Figure 4.

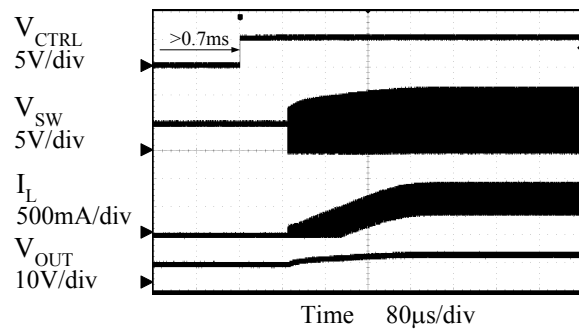


Figure 4. Soft Start Waveform
 $V_{IN}=5V$, 3×13 LEDs, $I_{LED}=260mA$

Standby and Dimming

To avoid audio noise and achieve high frequency dimming, AP3031 set up a standby function. If logic low time on CTRL pin is less than about 0.7ms and then enable the IC, AP3031 will hold on standby mode and start directly to achieve high frequency dimming. Details please refer to Figure 5.

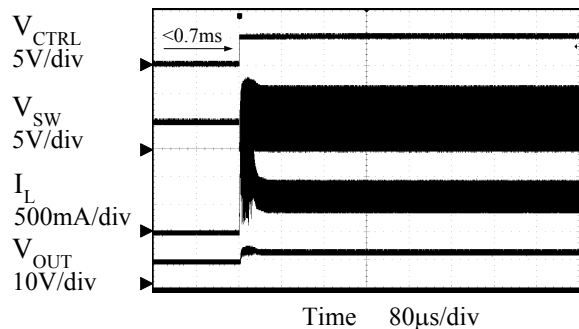


Figure 5. Standby Waveform

Two typical types of dimming control circuit are present as below. First, controlling CTRL Pin voltage to change operation state is a good choice. Second, changing the feedback voltage to get appropriate duty and luminous intensity is also useful.

(1) Adding a Control Signal to CTRL Pin

Adding a PWM signal to CTRL pin directly, the AP3031 is turned on and off by this signal. When the PWM frequency is lower than 1kHz(Typ.), the IC works in the soft-start mode to dimming the light. On contrary, when the PWM frequency is higher than 1kHz(Typ.), the IC works in the standby mode: the converter ceaselessly switches off and directly starts to achieve light dimming. This standby function allows AP3031 to support high frequency dimming (up to 25kHz or higher) to avoid audio noise. Great notice should be taken to the dimming PWM

frequency when it close to 1kHz, with duty cycle changes, IC may work both in soft-start mode and standby mode. This causes output current a discontinuity change which is not wanted. More details please refer to Figure 6 and Figure 7.

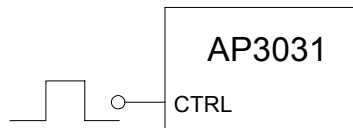


Figure 6. Dimming Control Using a PWM Signal in CTRL Pin

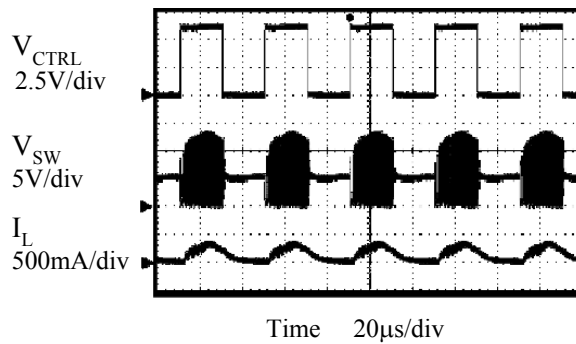


Figure 7. High Frequency (25kHz) Dimming Waveform

(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.

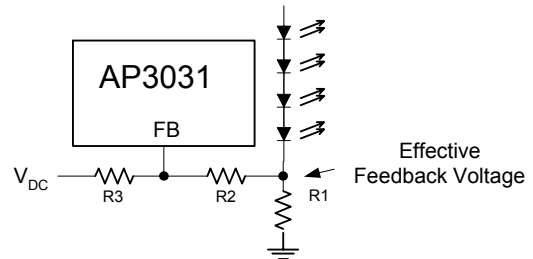


Figure 8. Dimming Control Using DC Voltage

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.

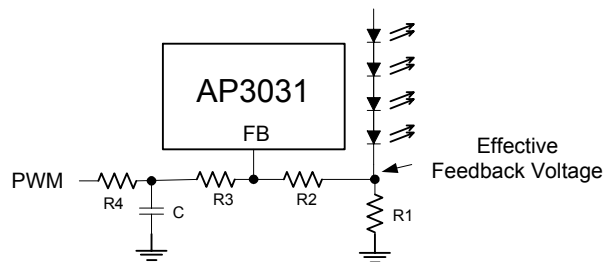


Figure 9. Dimming Control Using Filtered PWM Voltage