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## Simple circuit allows long PWM soft starts

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Available from multiple sources, the UC384X family of current-mode, PWM (pulse-width-modulated) power-supply controllers offers good performance and has spawned a variety of similar ICs. All members of the UC384X family and its variants share a common characteristic—an internal voltage-error amplifier that provides a current-limited output. Designated as the COMP pin, the amplifier's output provides a convenient connection for applying compensation to ensure overall feedback-loop stability. In addition, the COMP pin allows attachment of shutdown and soft-start circuitry and serves as a convenient point for setting an external power switch's output-current-limit threshold.

Two of the COMP pin's characteristics enhance its versatility: First, the pin delivers limited output current, and, second, the pin's voltage is directly proportional to the current flowing through an external power switch. Both features also allow the pin to

serve as a control port. For example, perhaps the most common application for the pin involves addition of a soft-start feature to a UC384X-based power-supply design.

In soft-start mode, an external power switch's output current and the power supply's output voltage ramp up at a rate controlled by, and proportional to, the voltage at the COMP pin. **Figure 1** shows a typical soft-start circuit's implementation comprising a small-signal PNP transistor,  $Q_1$ , connected to the COMP pin. An RC network,  $R_1$  and  $C_{SS}$ , drives  $Q_1$ 's base from IC<sub>1</sub>'s internally generated, 5V precision-reference source.

When the external power-supply voltage,  $V_{DD}$ , exceeds IC<sub>1</sub>'s internally preset UVLO (undervoltage-lockout) threshold, the 5V reference source switches on. The voltage on  $C_{SS}$  ramps upward toward 5V at a rate that the time constant,  $\tau$ , of  $R_1 \times C_{SS}$  determines in seconds. Given  $Q_1$ 's emitter-follower configuration,  $Q_1$  applies the COMP

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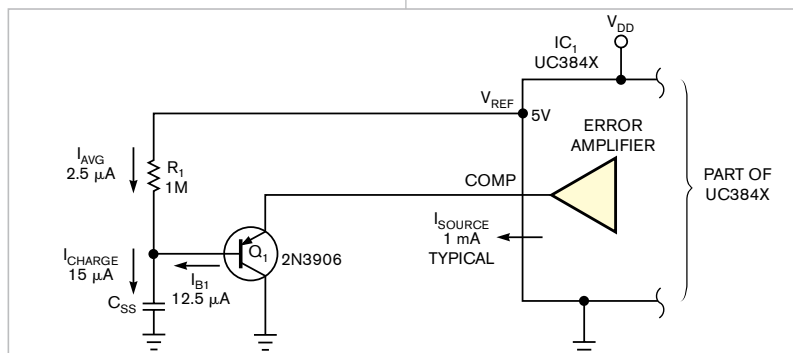
90 LED drivers minimize power dissipation

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pin's voltage, which "follows"  $Q_1$ 's base voltage, and the power supply's output current ramps up proportionally.

The simple circuit in **Figure 1** satisfies the requirements of many soft-start applications. To obtain longer soft starts, you can increase  $C_{SS}$  or increase  $R_1$  to decrease  $C_{SS}$ 's charging current. However, increasing either component can cause problems. Depending on the construction of capacitor  $C_{SS}$ , its leakage current may be significant. Also, you can no longer ignore  $Q_1$ 's base current. For example, a survey of PWM-control-IC designs shows that the COMP pin typically sources an output current of 1 mA. If  $Q_1$ , a 2N3906, provides a minimum beta of 80,  $Q_1$ 's base draws a minimum current of 12.5  $\mu$ A. The base current flows from the base pin of  $Q_1$  and adds to  $C_{SS}$ 's charging current. If the circuit in **Figure 1** uses a 1- $\mu$ F capacitor for  $C_{SS}$  and a 1-M $\Omega$  resistor for  $R_1$ , you would expect a nominal 1-second charging-time constant and an average charging-current flow of 2.5  $\mu$ A. However, the charging current actually totals 15  $\mu$ A—the sum of the 2.5- $\mu$ A charging current plus  $Q_1$ 's 12.5- $\mu$ A base current, and the soft-start time falls considerably short of the nominal value.

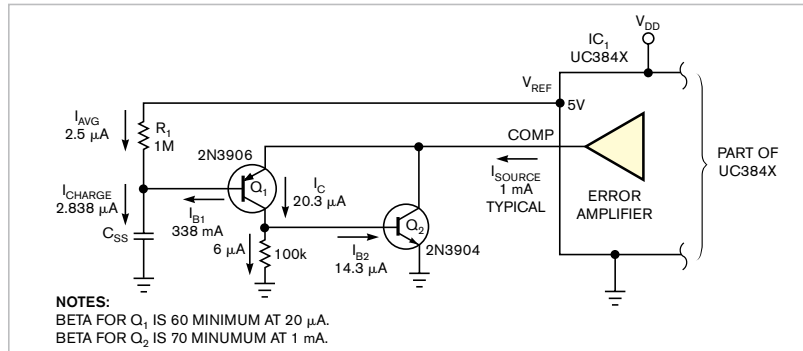
As an alternative, the circuit of **Figure 2** better satisfies designs such as



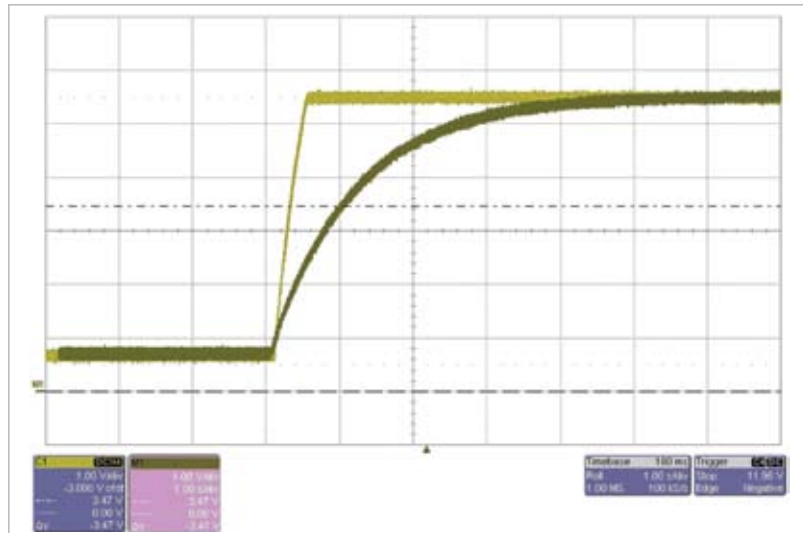
**Figure 1** A single transistor,  $Q_1$ , implements a switching regulator's slow-start-up feature, but its base current introduces a timing error.

battery chargers that require a longer soft start or a more accurately timed soft-start ramp. Adding a second transistor to form a PNP-NPN compound transistor maintains the slow-start function. The circuit's composite current gain (beta) consists of the product of  $Q_1$ 's and  $Q_2$ 's current gains, or  $70 \times 60 = 4200$ , which greatly exceeds the single transistor's current gain of 60. The higher current gain reduces the charging current's base-current component to only 338 nA. **Figure 3** compares the responses of both circuits. The dark-green trace shows that the circuit of **Figure 2** produces the expected 1-second soft-start time interval, and the light-green trace illustrates **Figure 1**'s too-brief start-up time. Although the circuit of **Figure 2** yields a more accurate soft-start ramp, it also allows the use of smaller capacitors, such as multi-layer ceramics, to reduce pc-board area and component cost.

Although a Darlington-connect-ed transistor pair would also provide high current gain, its output transistor cannot saturate—a prerequisite for keeping the off-state voltage at  $IC_1$ 's COMP pin below 1V. The PNP transistor,  $Q_1$  in the PNP-NPN compound connection in **Figure 2** can saturate, and the NPN transistor,  $Q_2$ , maintains its voltage-controlled saturation voltage at significantly less than 1V over the circuit's operating-temperature range. **EDN**




**Figure 2** Replacing  $Q_1$  in **Figure 1** with a PNP-NPN compound-transistor pair dramatically reduces the circuit's start-up-ramp-timing error.



**Figure 3** The dark-green trace shows that the circuit of **Figure 2** produces the expected 1-second slow-start time interval, and the light-green trace illustrates **Figure 1**'s too-brief start-up time. (The  $1\tau$  measurement equals 1 second.)

## Open-door alarm prevents accidental defrosts

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 Laboratory refrigerators and freezers often contain very valuable materials. Some units include overtemperature alarms that typically don't sound until thawing has already damaged the units' contents or sound when no one is around to hear the warning. Rather than a power outage, the most frequent cause of thawing disasters involves a failure on some-

one's part to properly close the freezer's door. This Design Idea describes an alarm that provides a timely open-door warning that can prevent an expensive incident.

A decade ago, a designer would have based this circuit on a type-555 timer IC, but, today, a small microcontroller provides a less expensive approach. The alarm in **Figure 1** detects an open

refrigerator or freezer door by means of a magnetic proximity switch that's available from Radio Shack ([www.radio shack.com](http://www.radio shack.com)) as an intrusion-alarm-system component. The circuit allows the door to remain open for a software-selectable interval—in this instance, 20 seconds—before activating a piezo-electric buzzer that conserves battery power by sounding for only 1 second of every 5.

A low-dropout voltage regulator,  $IC_1$ , an STMicroelectronics ([www.st.com](http://www.st.com)) L4931CZ50, provides 5V regulated power for  $IC_2$ , a Microchip ([www.micro](http://www.micro)



voltage on the order of 1V, which dissipates high power in the sense resistor ( $P_{SENSE} = V_{FB} / I_{LED}$ ). Reducing the sense resistor's value and adding an op amp to boost the sensed voltage reduces the power penalty (Figure 2). In some cases, you can eliminate the op amp by using a stable reference voltage, which is available on some converter ICs, to pull up the sense voltage (Figure 3).

## THE VARIATION OF LED CURRENT AVERAGES APPROXIMATELY 5 mA OVER AN INPUT-VOLTAGE RANGE OF 4 TO 5.5V.

The switching converter, a Maxim (www.maxim-ic.com) MAX1951, requires a feedback voltage of 800 mV and provides a 2V reference voltage at the reference pin. Connecting  $R_1$ , a 50-k $\Omega$  resistor, between  $R_S$  and  $V_{FB}$ , and  $R_2$ , a 100-k $\Omega$  resistor, between the reference and the feedback pins shifts the operating point from 200 mV at  $R_S$  to 800 mV at the feedback pin:

$$V_{FB} = V_{REF} \frac{50k}{50k + 100k} + V_{SENSE} \frac{100k}{50k + 100k} = 0.667V + \frac{2}{3}(V_{SENSE}).$$

Thus, for  $V_{SENSE} = 0.2V$ ,  $V = 0.8V$ . For the cost of two inexpensive resistors, power dissipation in the sense resistor diminishes by a factor of four.

Using the Luxeon K2 LED from Lumileds (www.lumileds.com), power measurements on the circuits of figures 1 and 3 illustrate how the feedback adjustment influences power that the LED driver delivers. Two graphs illustrate LED currents and voltages as a function of input voltage for a half-load of 400 mA (Figure 4) and a full load of 800 mA (Figure 5). As you would expect, the current regulation deteriorates at half-load. The variation of LED current averages approximately 5 mA over an input-voltage range of 4 to 5.5V and 1 mA for the circuit

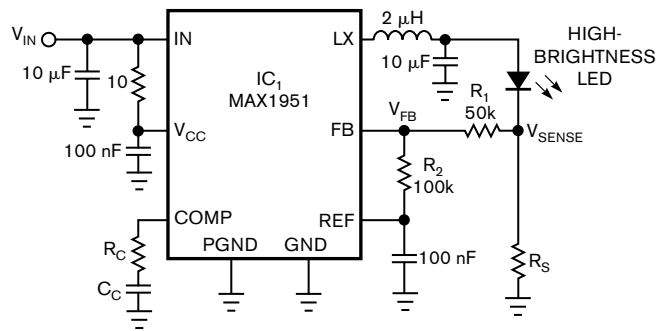


Figure 3 Adjusting the feedback signal improves the efficiency in this buck-converter driver for high-brightness LEDs.

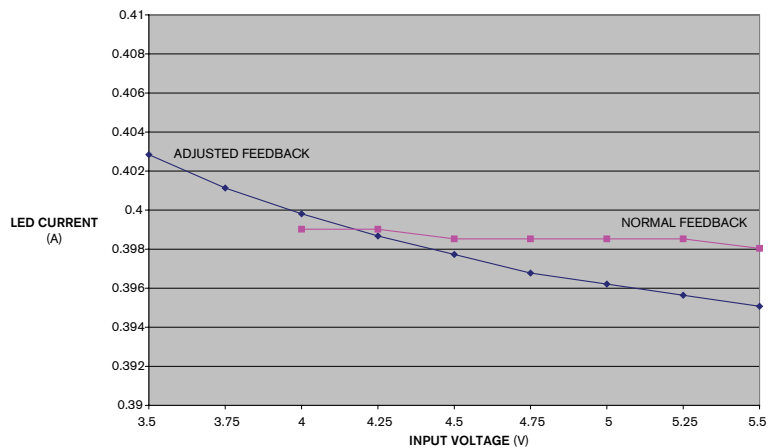


Figure 4 This graph shows LED current as a function of input voltage at half-load for the circuit of Figure 3.

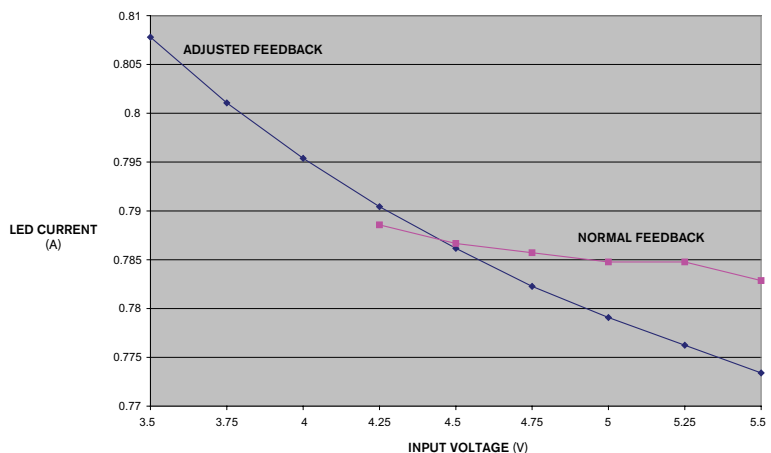


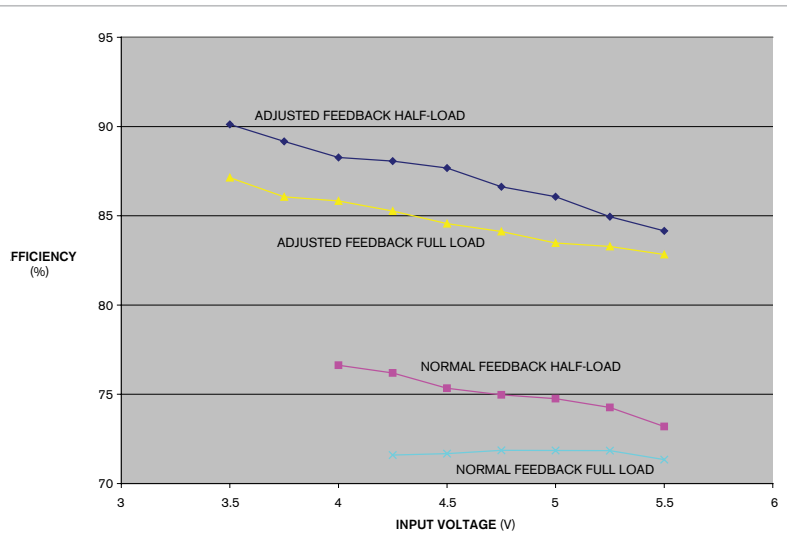
Figure 5 This graph shows LED current as a function of input voltage at full load for the circuit of Figure 3.

with normal feedback. The input-voltage range, however, increases by more than 0.5V. Regulation also deteriorates for full load, and the variation increases to approximately 22 mA versus 6 mA for the circuit with normal feedback (**Figure 6**). Again, the adjusted-feedback circuit of **Figure 3** increases the input-voltage range.

You can define the improvement in efficiency,  $\eta$ , as follows:

$$\eta = \frac{V_{LED} \times I_{LED}}{V_{IN} \times I_{IN}}$$

The buck converter's power-conversion efficiency and power dissipated in the sense resistor determine the circuit's efficiency. As **Figure 5** shows, the adjusted feedback of **Figure 3** increases the efficiency more than 10% at either half-load or full load. Assuming that the sense voltage doesn't change, efficiency improves for lower output-current loads because the sense resistor dissipates less power. **EDN**



**Figure 6** A comparison of a normal-feedback circuit (**Figure 1**) and an adjusted-feedback circuit (**Figure 3**) shows significant improvements in overall efficiency at half-loads and at full loads.

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