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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_1's internally generated, 5V precision-reference source.

When the external power-supply voltage, V_{DD}, exceeds IC_1'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, τ, of $R_1 \times C_{SS}$ determines in seconds. Given Q_1's emitter-follower configuration, Q_1 applies the COMP pin's voltage, which "follows" Q_1's base voltage, and the power supply's output current ramps up proportionally.

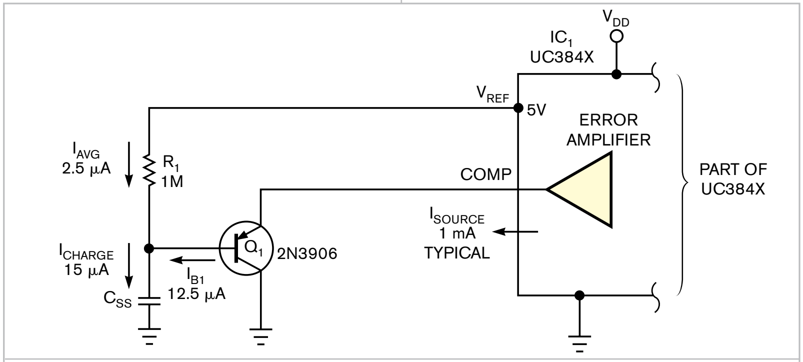

Figure 1 A single transistor, Q_1, implements a switching regulator's slow-start-up feature, but its base current introduces a timing error.

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 µA. 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-µF capacitor for C_{SS} and a 1-MΩ resistor for R_1, you would expect a nominal 1-second charging-time constant and an average charging-current flow of 2.5 µA through R_1. However, the charging current actually totals 15 µA—the sum of the 2.5-µA charging current plus Q_1's 12.5-µA 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

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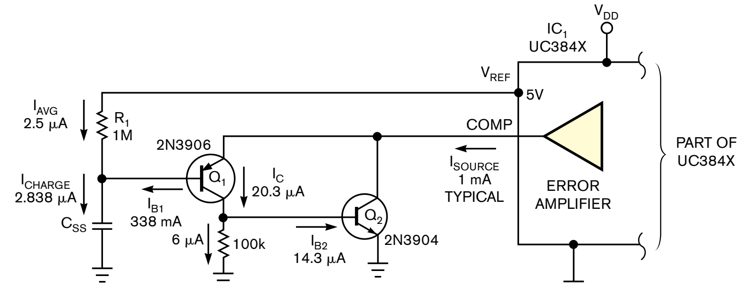
battery chargers that require a longer soft start or a more accurately timed soft-start ramp. Adding a second transistor to form a PNP-NPN compound transistor maintains the slow-start function. The circuit's composite current gain (beta) consists of the product of Q_1's and Q_2's current gains, or 70×60=4200, 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 multilayer ceramics, to reduce pc-board area and component cost.

Although a Darlington-connected 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



NOTES:
BETA FOR Q_1 IS 60 MINIMUM AT 20 µA.
BETA FOR Q_2 IS 70 MINUMUM AT 1 mA.

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.

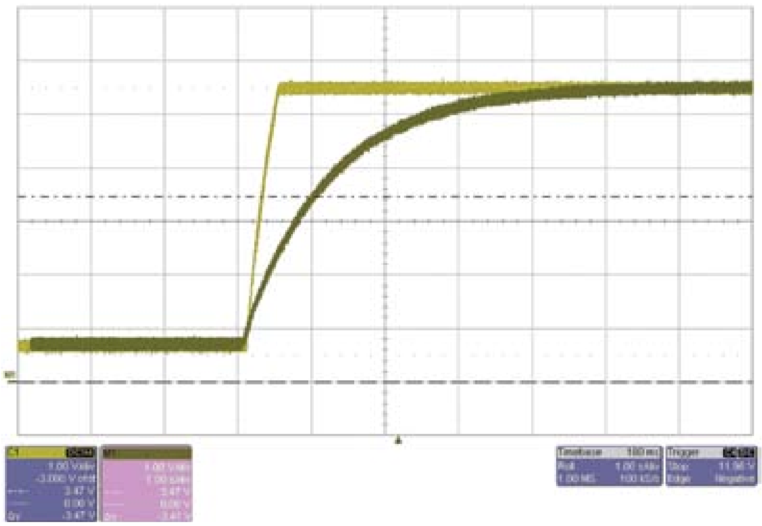


Figure 3 The dark-green trace shows that the circuit of Figure 2 produces the expected 1-second slow-start time interval, and the light-green trace illustrates Figure 1's too-brief start-up time. (The 1τ measurement equals 1 second.)

Open-door alarm prevents accidental defrosts

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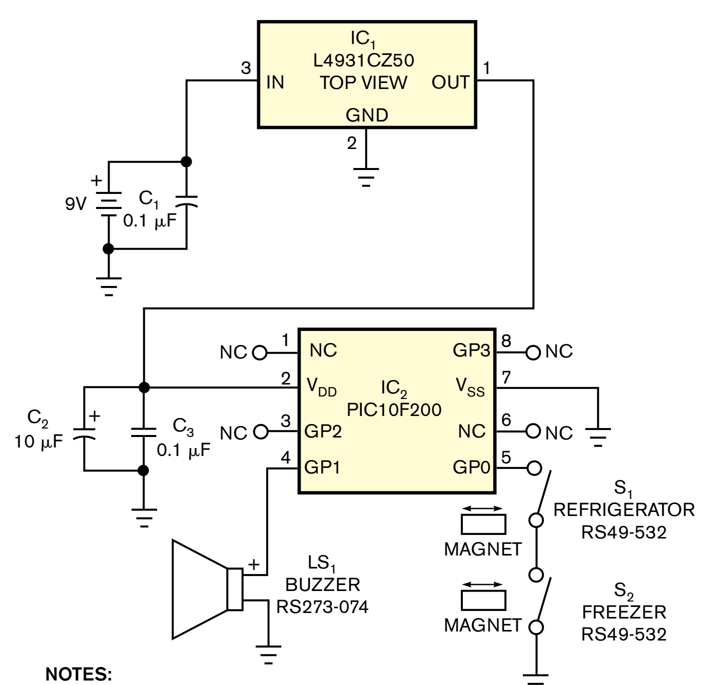
Laboratory refrigerators and freezers often contain very valuable materials. Some units include overtemperature alarms that typically don't sound until thawing has already damaged the units' contents or sound when no one is around to hear the warning. Rather than a power outage, the most frequent cause of thawing disasters involves a failure on someone'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.radioshack.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 piezoelectric 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) L4931CZ50, provides 5V regulated power for IC_2, a Microchip (www.micro chip.com) PIC10F200. Because IC_2 "sleeps" between door openings and voltage regulator IC_1 consumes little quiescent current, the 9V alkaline battery that powers the circuit offers a projected life of approximately one month. When you activate the buzzer, it consumes approximately 2 mA, a drive current that's directly available from the microcontroller's output port. At this current level, only an unencased piezoelectric element provides a sufficiently loud warning. In high-noise environments, you can use a solid-state relay or a logic-level MOSFET to drive the buzzer directly from the 9V battery.

You can attach the normally open switches and their actuation magnets to the refrigerator or freezer using double-sided adhesive-foam tape. The switches are sensitive to magnet orientation and position, making it easy to find a mounting configuration that can detect a door that's open by as little as 2 mm. Source code for the microcontroller is available for downloading from the online version of this Design Idea at www.edn.com/070201di1.EDN



NOTES:
RS DESIGNATES A RADIO SHACK PART NUMBER.
S_1 AND S_2 ARE NORMALLY HELD CLOSED BY THEIR RESPECTIVE MAGNETS.

Figure 1 This circuit protects the contents of a laboratory freezer or refrigerator by sounding an alarm when a door opens.

LED drivers minimize power dissipation

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One option for driving high-brightness LEDs uses the standard stepdown buck converter (**Figure 1**). The sense resistor, R_S, generates a feedback voltage, V_{FB}, that sets the desired LED current, I_{LED}, according to the equation $R_S=V_{FB}/I_{LED}$. Unfortunately, most buck converters require a relatively high feedback

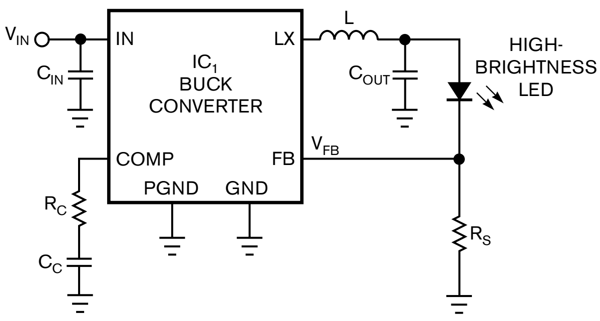

Figure 1 A generic buck converter, IC_1, provides constant-current drive for a high-brightness LED.

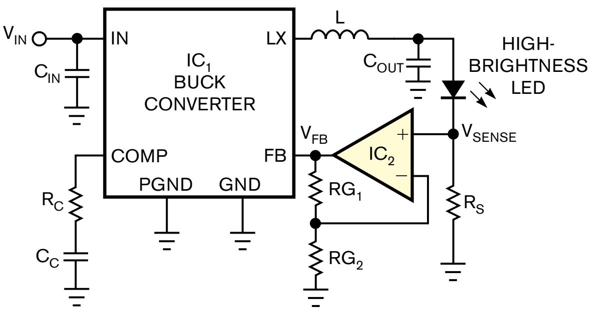

Figure 2 An op amp, IC_2, increases the LED-current error signal and reduces power dissipation in the sense resistor.

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-kΩ resistor, between R_S and V_{FB}, and R_2, a 100-kΩ 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:

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

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

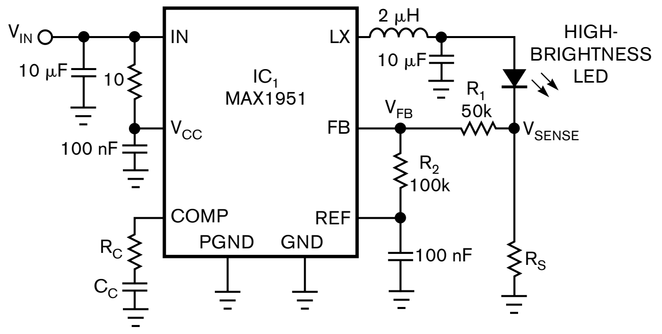

Figure 3 Adjusting the feedback signal improves the efficiency in this buck-converter driver for high-brightness LEDs.

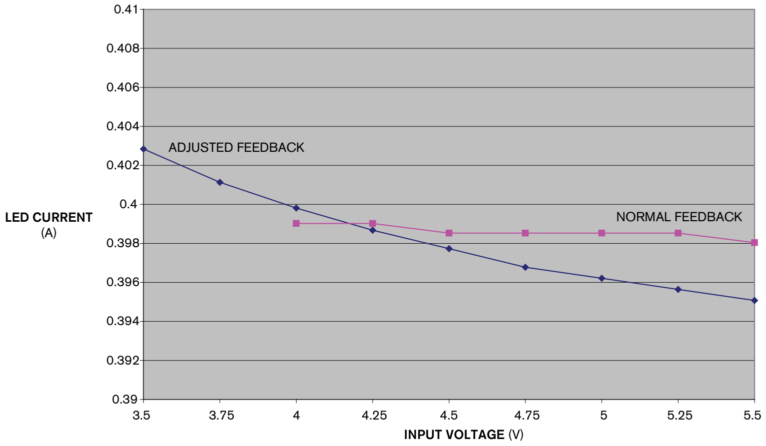

Figure 4 This graph shows LED current as a function of input voltage at half-load for the circuit of Figure 3.

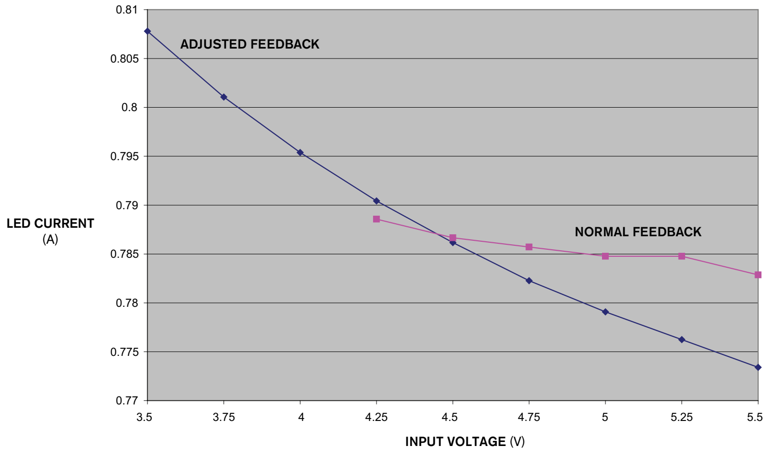

Figure 5 This graph shows LED current as a function of input voltage at full load for the circuit of Figure 3.

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, η, 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**

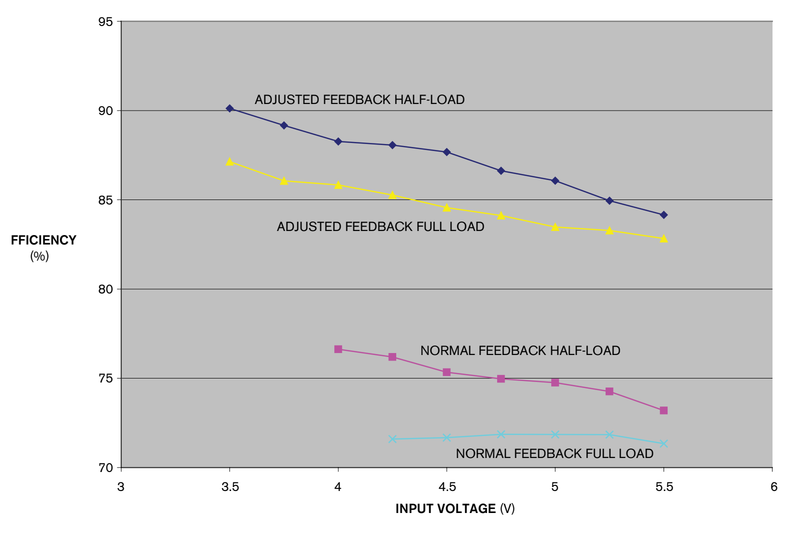

Figure 6 A comparison of a normal-feedback circuit (Figure 1) and an adjusted-feedback circuit (Figure 3) shows significant improvements in overall efficiency at half-loads and at full loads.