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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.

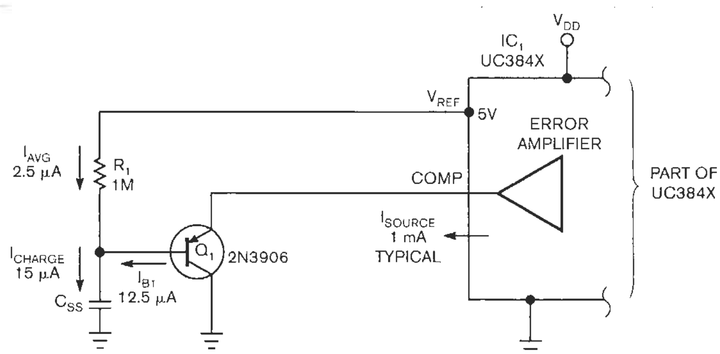
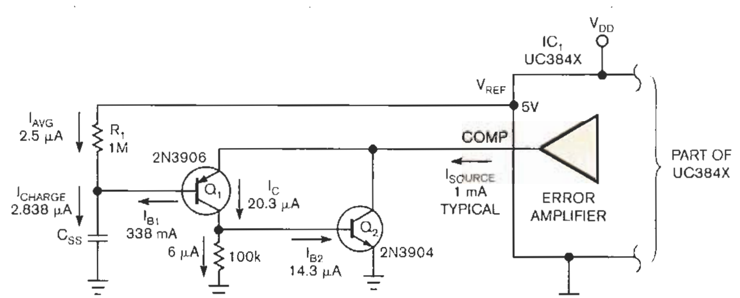


Figure 1 A single transistor, Q_1, implements a switching regulator's slow-start-up feature, but its base current introduces a timing error.

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 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.

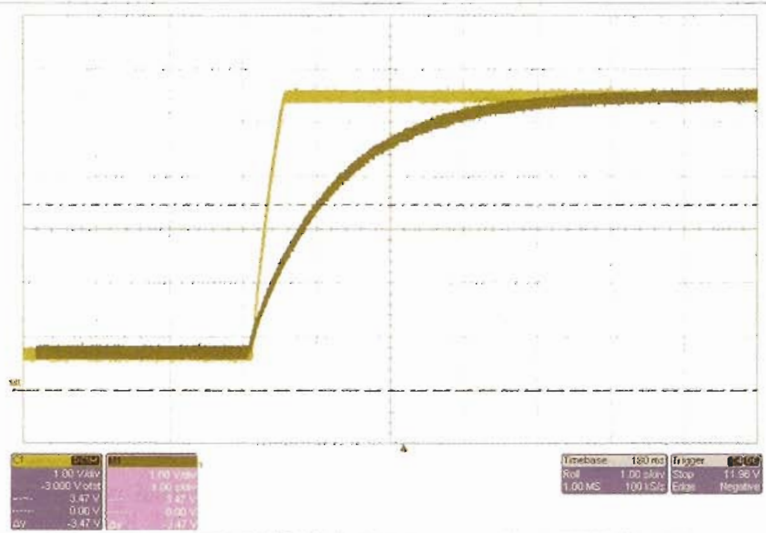


Figure 3 The dark-green trace shows that the circuit of Figure 2 produces the expected 1-second slow-start time interval, and the light-green trace illustrates Figure 1's too-brief start-up time. (The 1τ measurement equals 1 second.)