EDITED BY CHARLES H SMALL
AND FRAN GRANVILLE

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READERS SOLVE DESIGN PROBLEMS

Use a CFL ballast to drive LEDs

Christian Rausch, Unterhaching, Germany

Designers use ballast ICs, such as International Rectifier's (www.irf.com) IR53HD420, in CFLs (compact fluorescent lamps) for heating the filaments, igniting the lamps, and supplying the lamps with current (**Reference 1**). Manufacturers produce these ICs in high volumes, and they cost approximately \$2. This Design Idea shows how you can use a CFL-ballast IC for driving LEDs instead of CFLs. A ballast IC essentially is a self-oscillating half-bridge for offline operation. It typically operates from 320V dc, which is approximately the same power as that from a 230V-ac mains rectifier or a 120V voltage doubler. The IC generates square-wave voltages with an amplitude of 320V p-p and a frequency of tens of kilohertz.

Usually, this square-wave voltage connects to a series combination of a CFL tube and a current-limiting inductor, L_1 (**Figure 1**). Together with a parallel capacitor and using the LC resonance, you can warm up, ignite, and supply the tube with current. This approach works well because CFL tubes have high impedances when they are off and low impedance when they are running. The tube voltage is typically 150V p-p.

By putting several LEDs in series and connecting them to a bridge rectifier, you can effect an imitation of a CFL, at least in the on-state. Imitating the off-state is less important, because LEDs need no ignition procedure. At the given values for R_T and C_T, the bridge runs at 70 kHz. The circuit supplies 64 LEDs with a current of approximately 80 mA. The infrared LEDs illuminate the field of view of a CCD camera in a machine-vision system. The circuit prototype uses a 2.7-mH inductor from a dead CFL.

The LED current comprises dc current plus a small ripple current; keep

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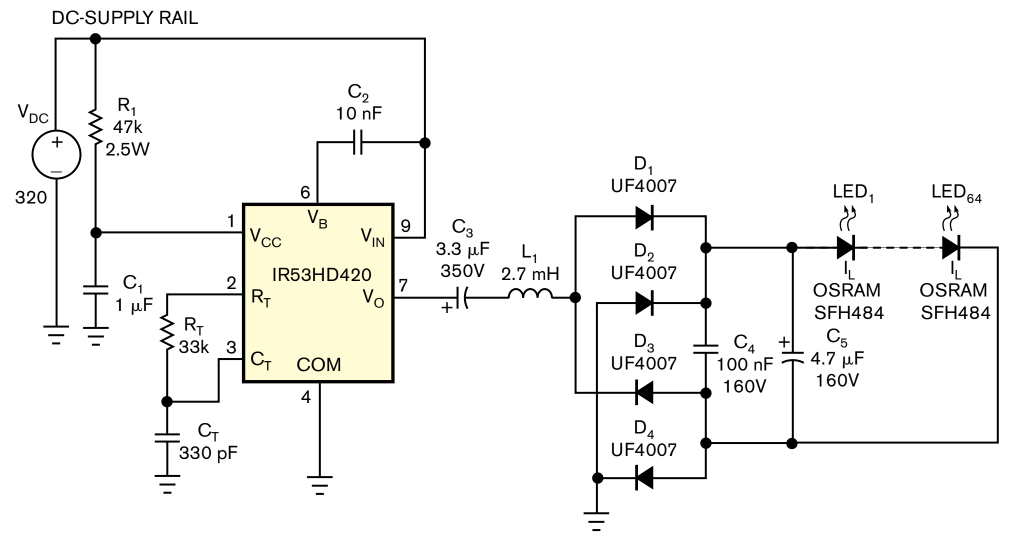

Figure 1 A CFL ballast drives a long string of LEDs.

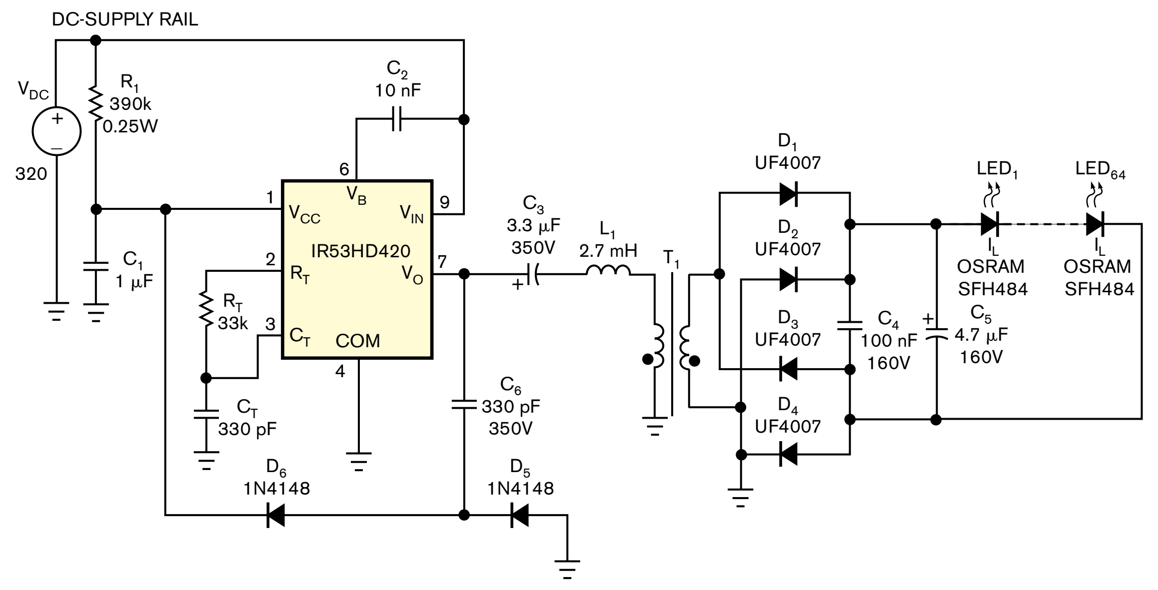

Figure 2 Adding a transformer to the circuit of Figure 1 allows you to connect as many LEDs as necessary.

the ripple current low for high efficiency and long LED lifetime. LED manufacturers usually demand values of a few percentage points. Such a low ripple current may be difficult to achieve with one electrolytic capacitor, C_5, but a parallel combination with an additional foil capacitor, C_4, works well enough in most cases. The voltage at the input of the LED rectifier is fairly constant during one oscillation period, so the inductor current has a triangular shape, which is good for EMC (electromagnetic compatibility). The equation for the average LED current is $I_{LEDAVG}=(½\times V_{DC}-N\times V_{FLED})/(4\times f\times L_1)$, where V_{DC} is the supply voltage, N is the number of LEDs in series, V_{FLED} is the LED forward voltage, f is the oscillation frequency, and L_1 is the inductance of the current-limiting inductor.

Although the circuit of **Figure 1** works well, it has some deficiencies that the circuit of **Figure 2** remedies by adding C_6, D_5, D_6, and T_1, wound on an EPCOS EP13 coil former, with an ungapped-EP13-core of T38 material with an inductance of 7000 nH. Both the primary and the secondary windings are 90 turns of 0.2-mm wire; the secondary winding is wound on top of the primary winding. Stray inductance is not important in this case, and the inductance for both the primary and the secondary windings is 50 mH. The circuit in **Figure 2** has several advantages over the one in **Figure 1**. For example, the supply current for the ballast IC of **Figure 1** must flow through R_1 and into the IR53HD420, where it gets clamped to 15.6V. At a supply current of about 6 mA, R_1 must dissipate more than 2W. In **Figure 2**, R_1 can have a much higher value, because it must supply only a small start-up current. After start-up, a charge pump comprising C_6, D_5, and D_6 pumps enough current into the V_{CC} pin so that the internal zener diode clamps to 15.6V. The design equation for the charge pump is $I_{SUPPLY(AVG)}=f\times C_6 2\times V_{DC}-15.6V$. The dissipation of R_1 now stays below 0.25W.

WITH THE TRANSFORMER, YOU CAN GROUND ONE END OF THE LED STRING EITHER DIRECTLY OR THROUGH A CAPACITOR.

Also, the summed forward voltages of the LEDs in **Figure 1** must be smaller than one-half the supply voltage. For the circuit in **Figure 2**, by tailoring the transformer-winding ratio, you can connect as many LEDs as needed, as long as you do not exceed the ratings of the components. (LED voltages even higher than V_{DC} are possible.) A less obvious problem of the circuit in **Figure 1** is that the full voltage swing of the bridge appears at both ends of the LED string. This situation does not present a problem when all the LEDs are close together and the LEDs are close to the bridge. However, in many light fixtures, you wish to separate the LEDs from the electronics. Due to stray capacitances, this approach would lead to high capacitive currents from the LEDs to ground, corrupting the efficiency and producing EMC problems. With the transformer of **Figure 2**, you can ground one end of the LED string either directly, as shown, or through a capacitor. Now, you can use long cables to easily separate the LEDs from the electronics.**EDN**

REFERENCE

1 "IR53H420(D)420, Self-Oscillating Half Bridge," Preliminary Data Sheet No. PD60140-K, International Rectifier, Aug 19, 2003, www.irf.com/product-info/datasheets/data/ir53h420.pdf.

Photodiode amplifier exhibits one-third the output noise of conventional transimpedance amp

Glen Brisebois, Linear Technology Corp, Milpitas, CA

A conventional 1-MΩ transimpedance amplifier has at least 130 nV/$\sqrt{\text{Hz}}$ of output-noise density at room temperature (**Figure 1**). You can consider the 130 nV as the theoretical noise floor limit of the amplifier because that is the noise density of the 1-MΩ resistor itself. Any noise in the op amp can only make things worse. Cooling the resistor to 77.2K, the temperature of liquid nitrogen, quiets it to 65 nV/$\sqrt{\text{Hz}}$, provided that it survives, but is that the only option? Can you beat the 130-nV theoretical noise floor without cooling?

Figure 2 shows one way. IC$_1$, a Linear Technology (www.linear.com) LTC6240, provides an overall transimpedance gain of 1 MΩ, but it has an output-noise density of only 43 nV/$\sqrt{\text{Hz}}$, about one-third of a conventional 1-MΩ transimpedance amplifier at room temperature. It achieves this figure by taking an initial transimpedance gain of 10 MΩ and then attenuating by a factor of 10. The transistor section provides voltage gain and works on a 54V supply voltage to guarantee adequate output swing. By achieving an output swing of 50V before attenuation, the circuit maintains an output swing to 5V after attenuation. The 10-MΩ resistor sets the gain of the transimpedance-amplifier stage and has a noise density of 400 nV/$\sqrt{\text{Hz}}$. After attenuation, the amplifier's effective gain drops to 1 MΩ, and the noise floor drops to 40 nV/$\sqrt{\text{Hz}}$, which dominates the observed 43 nV/$\sqrt{\text{Hz}}$. To achieve this noise performance by cooling requires a temperature of 33K, much colder than liquid nitrogen. Note also that the additional benefit of this method is that it divides the offset voltage of the op amp by 10. The worst-case output offset for this circuit is 105 μV over temperature. Bandwidth is 28 kHz.EDN

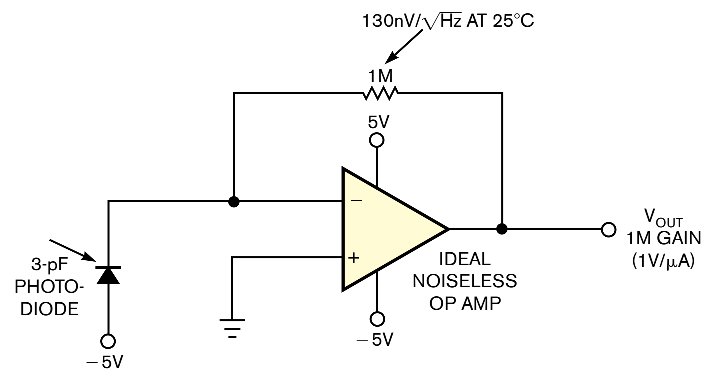

Figure 1 A conventional 1-MΩ transimpedance amplifier exhibits 130 nV/$\sqrt{\text{Hz}}$ of output noise, even with a noiseless op amp. Cooling the resistor reduces the noise, but can you do better without cooling?

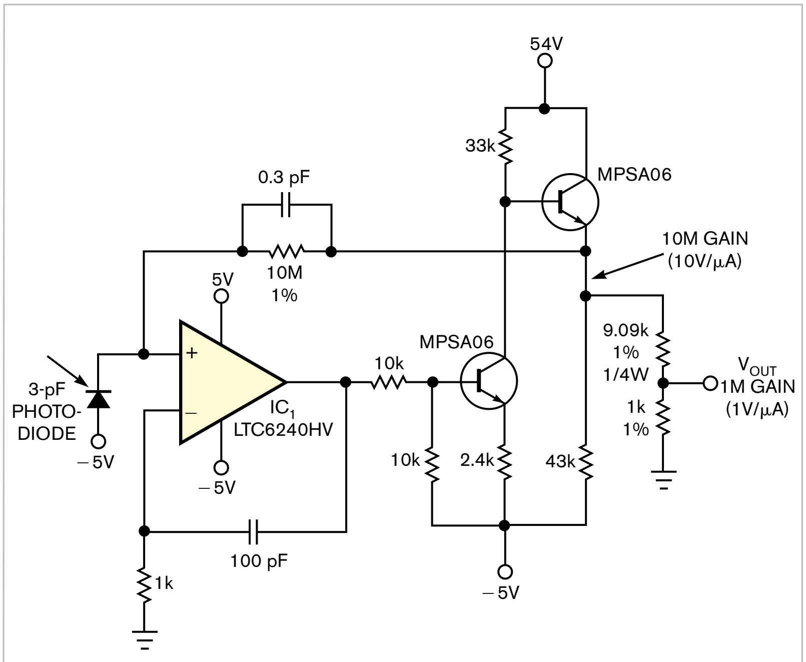

Figure 2 This effective 1-MΩ transimpedance amplifier has only 43 nV/$\sqrt{\text{Hz}}$ of output noise. The circuit takes 10 times the high amplifier gain and then attenuates by a factor of 10. The LTC6240 has low current and voltage noise. The discretes allow for high output swing at the 10-MΩ gain node, so that a 0 to 5V output swing remains after attenuation.

Microcontroller programmer taps power from PC's serial port

GY Xu, XuMicro, Houston, TX

Just like a PC's USB port, the serial port on a PC can also in some cases serve as a power supply. A USB port can provide as much as 500 mA at 5V, but a serial port provides less power. Even with the serial port's limited capacity, serial-port power can still be a convenient power source for today's electronics. One obvious example is to light up an LED. **Figure 1** shows a simple way to tap the serial port's power. Under Windows XP, this task requires appropriate software. You can download the **listings** for this Design Idea from www.edn.com/070426di and run the program pwon.exe for this demo.

A far more useful case is to provide a power supply for the microcontroller programmer, which has no wall wart. Today's microcontrollers consume less current than their predecessors, so you can easily tap the serial port's power for an Atmel (www.atmel.com) AVR programmer (**Figure 2**). The programmer uses only two chips: IC_1, a Maxim (www.maxim-ic.com) DS275 for the RS-232 interface between the programmer and the PC, and IC_2, an Atmel AT89C2051 firmware microcontroller, which is the heart of programmer and handles all programming chores and communications with the PC. IC_3 is the AVR microcontroller, an AT90S1200/2313. You can also substitute an eight-pin AT90S2323/2343 or a 40-pin AT90S4414/8515. The SPI (serial-peripheral-interface) bus performs the device programming.

The basic requirement is that the circuit's total current consumption must be less than 10 mA. The programmer uses two RS-232 pins: DTR (data-terminal ready) and RTS (request to send) as a minuscule power source. The

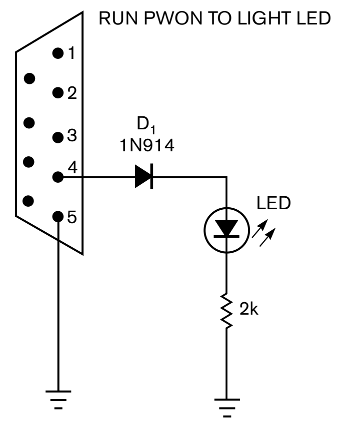

Figure 1 With the aid of a simple PC program, you can tap a PC's serial port for enough power to light an LED.

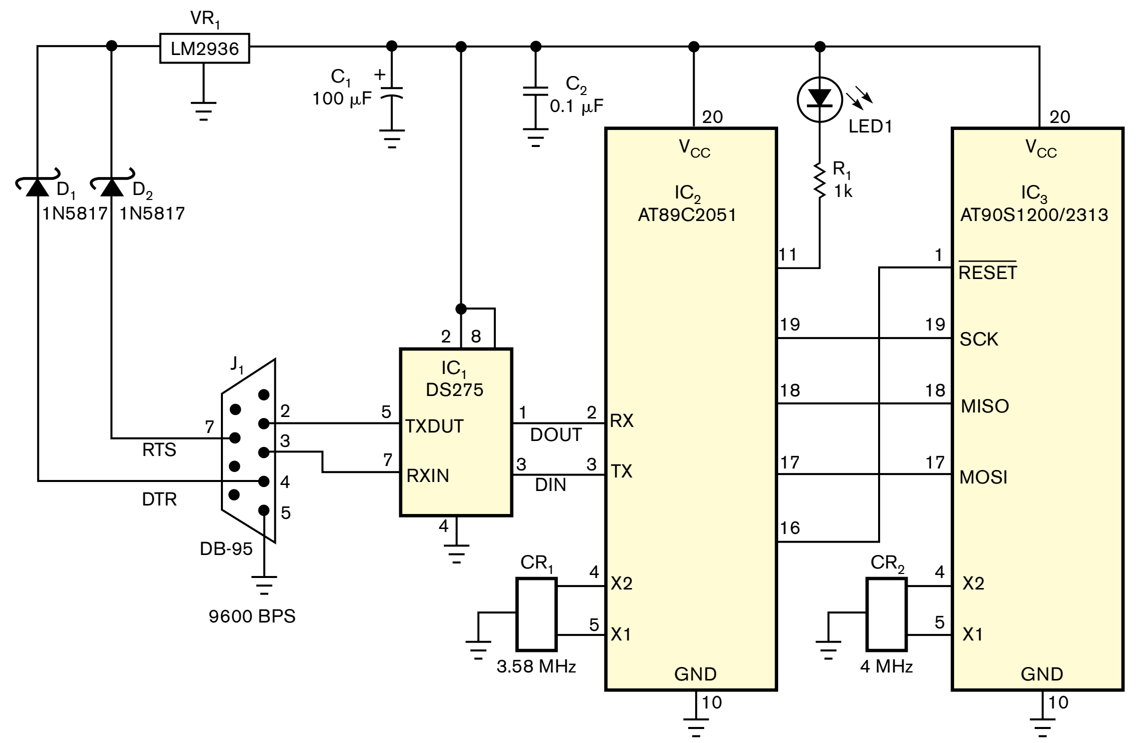

Figure 2 This microcontroller programmer gets its power from the PC's serial port.

outputs from these pins arrive at a pair of Schottky diodes, D_1 and D_2, which cause a forward-voltage drop of only 0.3V, and then to VR_1, an LM2936 low-dropout-voltage regulator. Capacitors C_1 and C_2 smooth the output voltage. To reduce current consumption, LED_1 uses a 1-kW current-limiting resistor, and the control firmware turns it on only after the programming task completes; otherwise, LED_1 is off.

The circuit for the programmer is easy to build. The 8051-like AT89C2051 has 2 kbytes of flash program memory. It needs no components connected to the reset (Pin 1), and it uses the 3.58-MHz ceramic resonator to generate 9600 bps for communication with the host PC. In addition to eliminating an external power supply, the programmer needs only firmware design. The programmer uses the Windows HyperTerminal program to communicate with the programmer firmware. You configure the HyperTerminal to use a COM port with 9600 bps and set the flow-control parameter to XON/XOFF.

You can program the firmware files in **Listing 1** into the AT89C2051 using any 8051 programmer, and the **listing** includes one AVR sample demo file to program into the AT90S1200/2313.EDN

Circuit charges supercapacitors to 7V from USB power

Fran Hoffart, Linear Technology, Santa Clara, CA

Charging a supercapacitor from a 5V USB port may seem simple at first, but to charge three supercapacitors to 7V and to limit the input current to the 500 mA maximum limit on the USB port is somewhat more difficult. The circuit in this Design Idea uses a Linear Technology (www.linear.com) LTC3458 switching regulator to charge three series-connected supercapacitors and provide input-current limiting. This regulator limits the input current, as the capacitors charge, to less than 500 mA to satisfy USB specifications, and it provides the boost function to charge the capacitor to a voltage greater than the 5V USB input. Once the supercapacitor charges, the regulator maintains 7V at the output and can supply a continuous load of approximately 300 mA in addition to brief current surges of several amperes without exceeding 500 mA at the input. Typical loads requiring high surge current can include motors when initially starting up.

Removing the input voltage shuts down the regulator and reduces the capacitors' discharge current to approximately 3 μA, essentially the current through the voltage programming resistors. Manual shutdown is also possible by pulling the shutdown pin low, but, with the input voltage still applied, the capacitors' discharge current increases to approximately 30 μA. The circuit in **Figure 1** is programmed for a switching frequency of 1 MHz with an output voltage of 7V. A resistor on

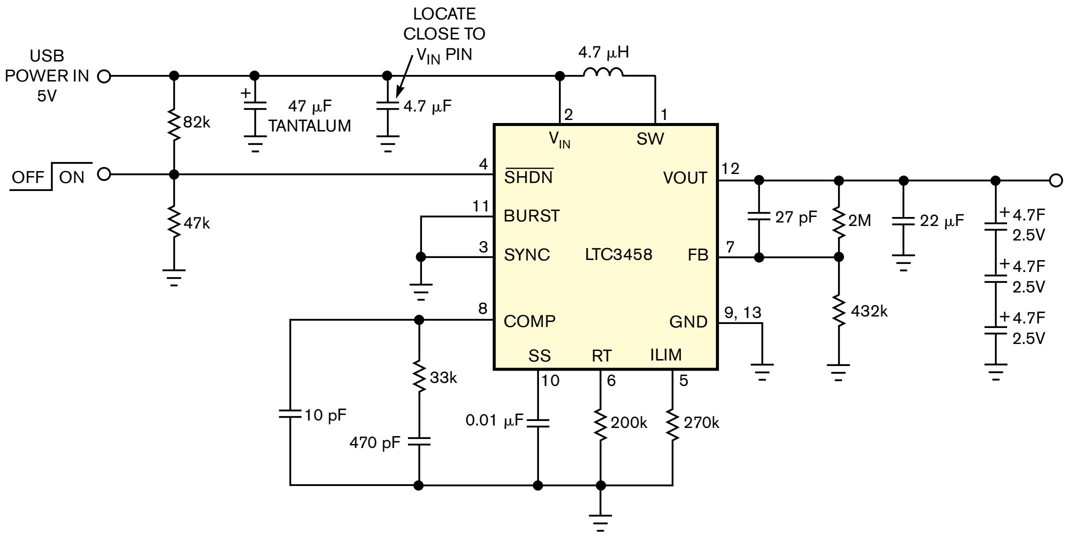

Figure 1 This circuit has a switching frequency of 1 MHz and an output voltage of 7V.

the current-limiting pin, ILIM, sets the input-current limit. The circuit contains all surface-mount components, and the high switching frequency allows the use of tiny inductors and capacitors, thus reducing total circuit size. You should use good PCB (printed-circuit-board)-layout practices.

The series-connected Polystor aerogel supercapacitors, available from various online sources, are each rated at 4.7F at 2.5V and feature a typical ESR (equivalent-series resistance) of 25 mΩ, thus allowing high discharge current. Low leakage current provides long capacitor-voltage-holdup time. The individual capacitor voltages track within 100 mV when charging and charge completely in less than 60 seconds at the rated charge current. **Figure 2** shows the capacitors' voltage, charge current, and resulting current drawn from the USB port when charging. **EDN**

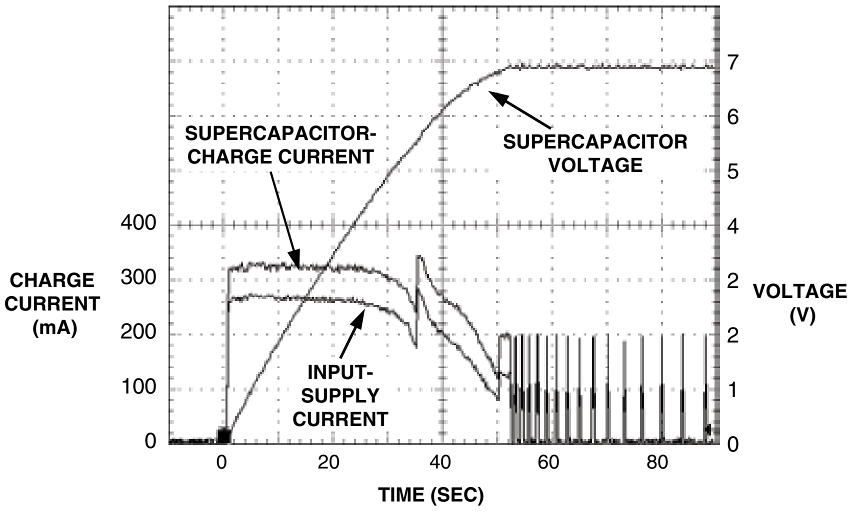

Figure 2 These curves show the super capacitors' voltage and charge current. Note that the charging current is 300 mA–the USB maximum allowable current draw.