[Design Briefs]

Single Alkaline Battery Drives White LED

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Although the boost circuit in Figure 1 comes off as rather simple (only two npn transistors), its benefits include low startup voltage and long battery life. White LEDs have gained immediate popularity because of their high brightness and multiwavelength spectrum. These characteristics can be extended to single-alkaline battery portability if the drive circuit can start from a low input voltage (<1.5 V).

White LEDs typically require 3.6 V at 20 mA (max) for proper operation. So an inductive dc-dc boost circuit solves the requirement of outputting a higher voltage than its input. Previous LED boost drivers required a V_{BE} plus a V_{SAT} to start up (approximately 1 V)—and many more components. Figure 1's circuit has only a few components and starts at a V_{BE} around 0.7 V. This lower startup voltage means that more of the battery energy is used (longer battery life).

The circuit description is cyclical, meaning there's a series of events that loops back on itself. The cycle starts with the battery voltage slightly above Q2's V_{BE}. This creates a positive Q2 base current:

i_B = (battery voltage • V_{BE})/R2

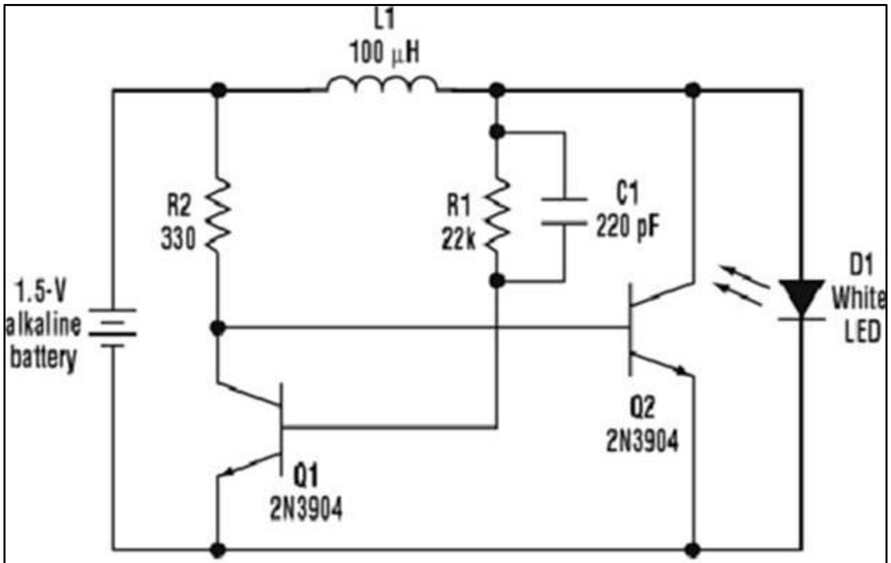
and Q2 turns on, thus switching inductor L1 to ground. Q1 is off. Energy stored within L1's magnetic field builds as L1's current rises with a positive di/dt. As this current rises, it also flows through Q2's R_{SAT} (D1 is off). Q2's collector voltage becomes sufficiently large to turn on Q1. Q1's base voltage is connected to Q2's collector by the feed-forward network of R1 and C1. R1 also serves as Q1's base current limit.

As Q1 turns on, the previous base drive to Q2 is then shunted to ground and Q2 turns off. The switching off of Q2 discharges L1's energy into the LED (D1) as the magnetic field collapses. This flyback action of L1 forward-biases D1, which gives up photon illumination in the form of white light. With L1 discharged, Q1 turns back off. The self-oscillating action repeats until the battery voltage falls below Q2's V_{BE}.

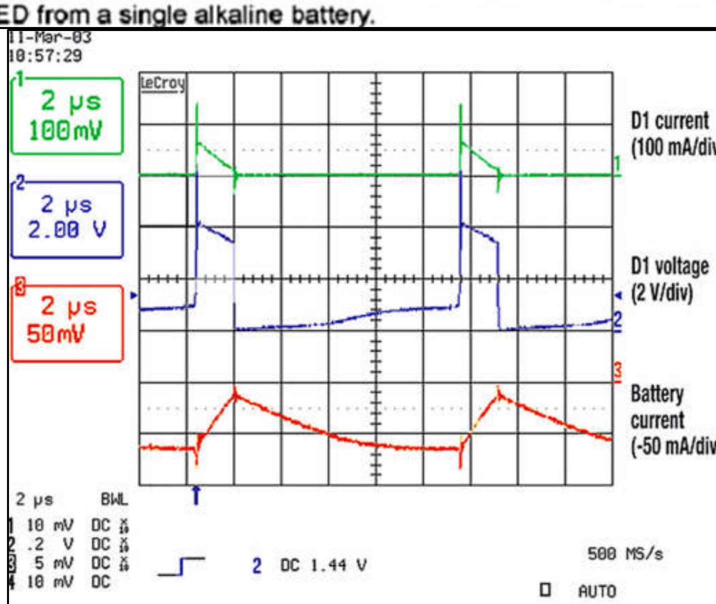
L1, Q2's R_{SAT}, and the switching characteristics of Q1 and Q2 dominate the period and duty cycle of this oscillation. LED brightness depends directly on the average current flow through D1. D1 is on while Q2 is off and off while Q2 is on.

The oscilloscope waveforms in Figure 2 show the battery current, D1 current, and D1 voltage during the switching period of 10.8 µs (93 kHz). With a 1.0-V battery voltage, the average battery current is 41 mA, and the average LED current is 14 mA. Using a Coilcraft DO1608-104 inductor and a Nichia BSPW500BS LED, the nominal input/output power efficiency is 23%, 34%, and 72% with a battery voltage of 0.8 V, 1.0 V, and 1.5 V, respectively.

There's a limitation on the largest battery voltage that can drive this boost circuit. Because the base of Q2 connects directly to the battery by R2, a battery voltage greater than 1.5 V will cause excessive Q2 base current. A single alkaline-cell battery (<1.5 V) is best. Yet, almost any discarded alkaline battery that comes out of portable electronics (toys, PDAs, and so on) will be able to start up this boost circuit and provide some illumination. Therefore, the usable lives of so-called dead batteries are extended—albeit in another application.



1. Using just a few components, this boost circuit can drive a white LED from a single alkaline battery.



2. These waveforms show the input current, LED voltage, and LED current with a battery voltage of 1.0 V.