Single cell lights any LED

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Figure 1

A simple circuit provides drive from a single cell to an LED of any type or color.

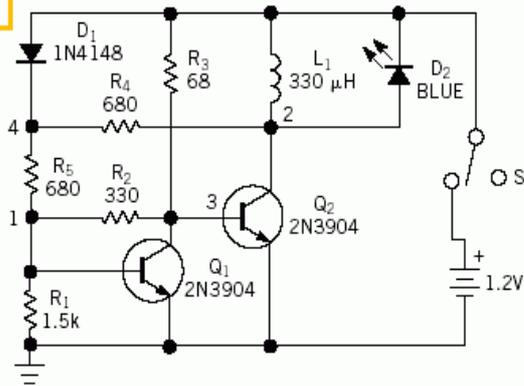THE CIRCUIT IN FIGURE 1 allows you to light any type of LED from a single cell whose voltage ranges from 1 to 1.5V. This range accommodates alkaline, carbon-zinc, NiCd, or NiMH single cells. The circuit's principal application is in LED-based flashlights, such as a red LED in an astronomer's flashlight, which doesn't interfere with night vision. White LEDs make handy general-purpose flashlights. You can use the circuit in **Figure 1** with LEDs ranging from infrared (1.2V) to blue or white (3.5V). The circuit is tolerant of the varying LED voltage requirements and delivers relatively constant power. It provides compensation for varying battery voltage. The circuit is an open-loop, discontinuous, flyback boost converter. Q_2 is the main switch, which charges L_1 with the energy to deliver to the LED. When Q_2 turns off, it allows L_1 to dump the stored energy into the LED during flyback.

Q_1, an inverting amplifier, drives Q_2, an inverting switch. R_4, R_5, and R_2 provide feedback around the circuit. Two inversions around the loop equal noninversion, so regeneration (positive feedback) exists. If you replace L_1 with a resistor, the circuit would form a classic bistable flip-flop. L_1 blocks dc feedback and allows it only at ac. Thus, the circuit is astable, meaning it oscillates. Q_2's on-time is a function of the time it takes L_1's current to ramp up to the point at which Q_2 can no longer stay in saturation. At this point, the circuit flips to the off state for the duration of the energy dump into the LED, and the process repeats. Because inductors maintain current flow, they are essentially current sources as long as their stored energy lasts. An inductor assumes any voltage necessary to maintain its constant-current flow. This property allows the circuit in **Figure 1** to comply with the LED's voltage requirement.

Constant-voltage devices, such as LEDs, are happiest when they receive their drive from current sources. The LED in **Figure 1** receives pulses at a rapid rate. The inductor size is relatively unimportant, because it determines only the oscillation frequency. If, in the unlikely case the inductor value is too large, the LED flashes too slowly, resulting in a perceivable flicker. If the inductor value is too small, switching losses predominate, and efficiency suffers. The value in **Figure 1** produces oscillation in the 50-kHz neighborhood, a reasonable compromise. D_1 provides compensation for varying cell voltage. By the voltage-division action at Node 4, D_1 provides a variable-clipping operation. The higher the supply voltage, the higher the clipping level, and the result is correspondingly less feedback. Q_1 inverts this clipping level to reduce the turn-on bias to Q_2 at higher cell voltages. We chose 2N3904s, but any small-signal npn works. Q_2 runs at high current at the end of the charging ramp. Internal resistance causes its base-voltage requirement to rise. The R_2-R_1 divider at Q_1's base raises the collector voltage to match that requirement and thus controls Q_2's final current.

The LED's drive current is a triangular pulse of approximately 120 mA peak, for an average of approximately 30 mA to a red LED and 15 mA to a white one. These levels give a reasonable brightness to a flashlight without unduly stressing the LED. The supply current for the circuit is approximately 40 mA. A 1600-mAhr NiMH AA cell lasts approximately four hours. L_1 must be able to handle the peak current without saturating. The total cost of the circuit in **Figure 1** is less than that of a white LED. You can use higher current devices and larger cells to run multiple LEDs. In this case, you can connect the LEDs in series. If you connect them in parallel, the LEDs need swamping (ballast) resistors. You can also rectify and filter the circuit's output to provide a convenient, albeit uncontrolled, dc supply for other uses.

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