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A Comparison of Light-Emitting Diode Power Supply Circuits

by Arthur Harrison

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14. ABSTRACT

In applications where LEDs use a large proportion of power and cell life is an important consideration, a power-conserving technique utilizing a switched circuit offers a considerable improvement in cell life. Two circuits, one utilizing a conventional method of resistive current limiting, and the other utilizing a switching method, were constructed and evaluated. The switching method yielded a 39% improvement in the duration of LED illumination.

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Overview

The Prognostics and Diagnostics program at the Army Research Laboratory uses various circuits that have light-emitting diodes (LEDs) as visible status indicators, powered by a 3-volt lithium cell. In these applications, where cell life is an important consideration, LEDs use a large proportion of power. This technical note provides the results of an experiment conducted to examine the merits of a power-conserving technique used in a LED power supply circuit.

Synopsis

A visible LED may be illuminated with a direct current provided by a 3v lithium cell, where the current delivered to the LED is determined by a series resistor, as shown in figure 1.

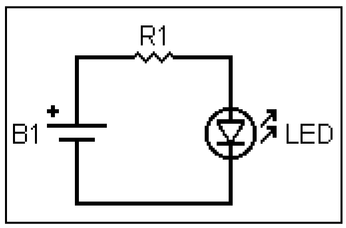

Figure 1. Simple LED circuit.

The LED current is defined by the equation:

$I_{LED} = (V_{B1}-Vf_{LED}) / R1 = 990$ microamperes (uA)

where:

B1 = 3 Volts (V) lithium cell

$V_{B1} = 3.0V$

$Vf_{(LED)}$ = Voltage across LED = 2.1V

R1 = Resistance = 909ohms

The voltage across the resistor, V_{R1}, 0.9V, results in a power loss defined by the equation:

$P_{loss} = (V_{R1})^2 / R1 = 0.891$ milliwatts (mW)

Another method for illuminating the same LED is to dispense with the resistor, and replace it with a semiconductor switch, metal oxide semiconductor field effect transistor (MOSFET), Q1, controlled with a rectangular waveform, as shown in figure 2.

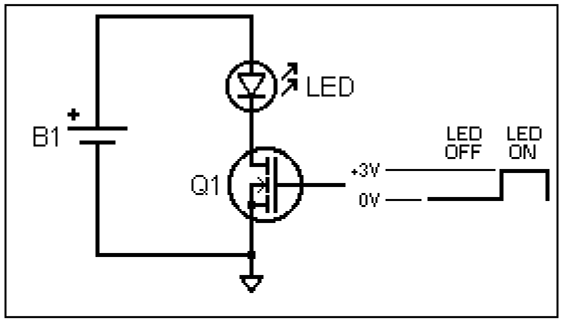

Figure 2. Switched LED circuit.

When 3V is applied to the gate of Q1, its channel resistance becomes less than 1ohm, providing nearly the full available cell current to the LED, limited only by the internal resistance of the cell, the on resistance of the MOSFET, and the resistance of the circuit's conductors. Since the MOSFET exhibits a very low on resistance of less than 1ohm, the associated power loss in the MOSFET is nearly zero.

If the MOSET were to remain on, the resulting steady-state current may exceed the LED's maximum power rating and damage it. However, by regulating the on time and frequency of the MOSFET gate waveform, the average brightness of the LED may be set to equal the same steady-state value obtained in figure 1, while still operating the LED within its allowable pulsed-mode ratings.

Figure 3 shows the practical circuit employed for implementing the switching scheme. The type CD40106BE complementary metal oxide semiconductor (CMOS) six-section inverting Schmitt trigger integrated circuit (IC) was used for its low voltage operation capability. A relaxation oscillator is comprised of inverting Schmitt trigger U1A in conjunction with frequency-determining components resistor, R1, and capacitor, C1. The oscillator provides a frequency of approximately 800Hz. The oscillator's output is followed by a differentiator, comprised of capacitor, C2, and resistor, R2, with inverting Schmitt trigger, U1B, providing waveform restoration. The values of C2 and R2 are selected to provide an appropriate on-off ratio (duty cycle) for the LED. The four remaining inverting Schmitt triggers serve as a gate driver for the MOSFET. Capacitors C3 and C4 provide bypassing for the cell, lowering the power supply impedance to prevent the LED current impulses from affecting the oscillator. The figure 3 circuit, exclusive of the LED, uses approximately 10uA of battery current, which amounts to a power loss of 30 microwatts (uW), which is approximately one-thirtieth the power loss apparent in the circuit of figure 1.

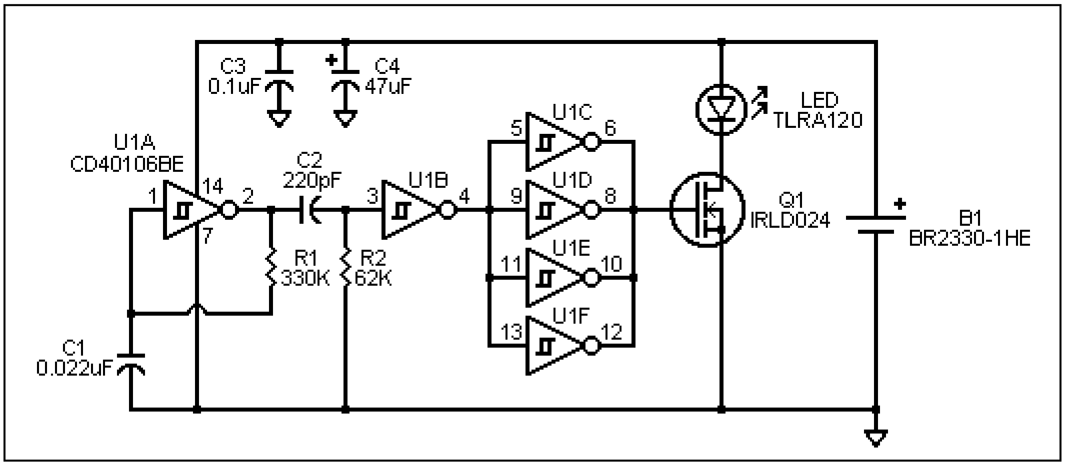

Figure 3. Schematic of circuit used for testing.

For the circuit shown in figure 3, the initial conditions were as follows:

MOSFET on time = 22uS
MOSFET off time = 1200uS
Oscillator frequency = 818Hertz (Hz)
LED duty cycle = 1.80%
Cell voltage = 2.25V with the LED on

After 500 hours, the conditions were:

MOSFET on time = 6uS
MOSFET off time = 2700uS
Oscillator frequency = 370Hz
LED duty cycle = 0.22%
Cell voltage = 2.40V with the LED on

The large variation in conditions results from the cell's voltage decrease during the test. More consistency of the timing parameters would be achieved in a system-based circuit employing a crystal-controlled timing generator, however, the autonomous circuit of figure 3 satisfied the requirement to evaluate the power-saving merits for a single LED, using a circuit with a minimum number of components.

Conclusion

The circuits of figures 1 and 3 were constructed with LEDs and power cells from the same lot, and were run concurrently. The brightness of the LEDs was evaluated on a subjective basis by several individuals, with the initial brightnesses being equal. After approximately 360 hours of continuous operation, the LED in figure 1 exhibited approximately half of its initial brightness, while the LED in figure 2 exhibited half of its initial brightness after approximately 500 hours, yielding a 39% improvement in duration. At 500 hours, the cell voltage in the figure 1 circuit was 1.50V, and the LED was almost completely extinguished.

References

Data Sheet, Toshiba TLRA120 LED.

Data Sheet, International Rectifier IRLD024 MOSFET.

Data Sheet, Panasonic BR2320-1HE Lithium Cell.

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