LINEAR TECHNOLOGY

DESIGN NOTES

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Switching Regulator Allows Alkalines to Replace NiCads

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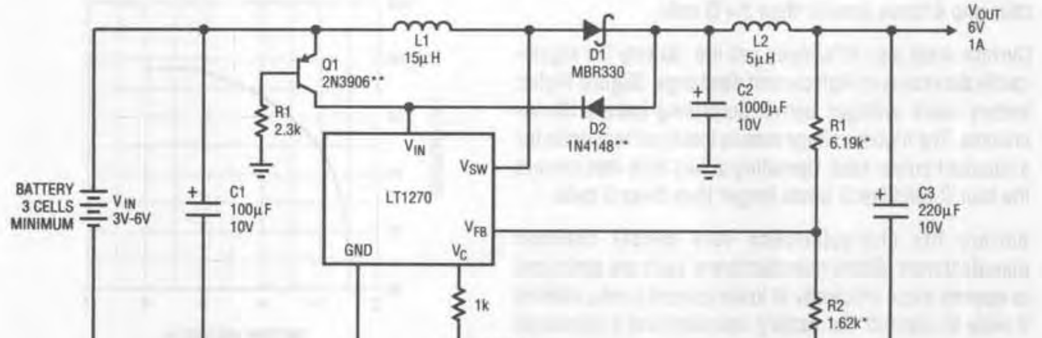
In many applications it is desirable to substitute non-rechargeable batteries for chargeable types. This capability is necessary when the NiCads can't be recharged or long charge times are unacceptable. Alkaline batteries are an excellent choice in this situation. They are readily available and have reasonable energy density. Compared to Alkalines, NiCads provide a more stable terminal voltage as they discharge. NiCads decay from 1.3V to 1.0V, while Alkalines drop from 1.5V to 0.8V. Replacing NiCads with Alkalines can cause unacceptable low supply voltage, although available energy is adequate. A boost type switching regulator obviates this problem, allowing Alkaline cells to replace NiCads. The circuit shown in Figure 1 accommodates the Alkaline cells widely varying terminal voltage while providing a constant output voltage.

This circuit is a step-up boost type switching regulator. It maintains a constant 6V output as battery voltage falls. The inductor accumulates energy from the battery when the LT1270 switch pin (V_{SW}) switches to ground and dumps its stored energy to the output when the switch pin (V_{SW}) goes off. The feedback pin (V_{FB}) samples the output from the 6.19k-1.62k divider. The LT1270's error amplifier compares the feedback pin voltage to its internal 1.24V reference and controls the V_{SW} pin switching current, completing a control loop. The output voltage can be varied by changing the resistor divider ratio. The RC damper on the V_C pin provides loop frequency compensation. The minimum start up voltage for this circuit is 3V. If a 3.3V start up voltage is permissible R1 and Q1 can be removed with D2 replaced by a short.



* = 1% FILM RESISTORS
** = OPTIONAL – FOR 0.3V LOWER START UP VOLTAGE
D1 = MOTOROLA – MBR330
C1 = NICHICON – UPL1A101MRH
C2 = NICHICON – UPL1A102MRH6
C3 = NICHICON – UPL1A221MRH
L1 = COILTRONICS – CTX15-8-52
L2 = COILTRONICS – CTX5-1-FR

$$V_{OUT} = 1.24V\left(1 + \frac{R1}{R2}\right)$$

Figure 1. Low Voltage Circuit Provides Constant Output Voltage as Battery Discharges

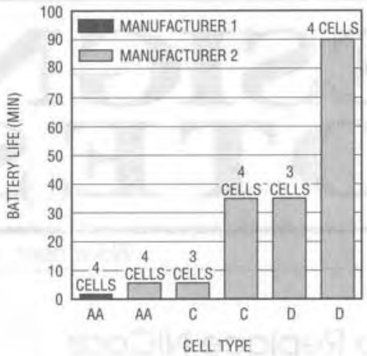


Figure 2. Battery Life Characteristics for Different Batteries for a 6W Load

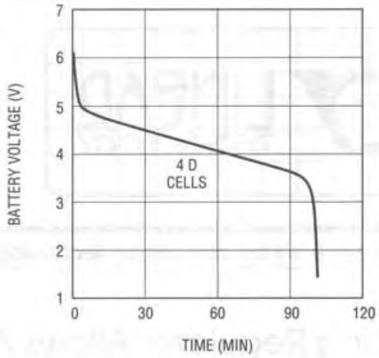


Figure 3. Alkaline Battery Discharge Characteristic with 6W Load

Bootstrapping the V_{IN} pin off the output voltage allows the battery voltage to drop below the minimum start up voltage, while maintaining circuit operation. For example, with three C cells the battery voltage is initially 4.5V and operates down to 2.4V. With this bootstrapped technique the circuit provides a constant output voltage over the battery's complete operating range, maximizing battery life.

Battery life characteristics are different for various cell types. Figure 2 compares battery life between AA, C, and D cells with a 6W load. In this application the power drain from the battery remains relatively constant. As the battery voltage decreases the battery current increases. The AA types discharge quicker than the C or D cells. They are physically smaller than the other cells, and therefore store less energy. The AA cells are 3 times smaller than the C cells and 6 times smaller than the D cells.

Current drain also influences cell life. Battery life significantly decreases at high current discharge. Slightly higher battery stack voltages permit surprising battery life increases. The higher voltage means lower current drain for a constant power load. Operating at just 33% less current the four C cells last 5 times longer than three C cells.

Battery life characteristics vary widely between manufacturers. Some manufacturers' cells are optimized to operate more efficiently at lower current levels, making it wise to consult the battery manufacturer's discharge characteristics.

Figure 3 shows Alkaline battery discharge characteristics for four D cells. A fresh cell measures 1.5V and operates down to 0.8V before the cell dies. The battery stack voltage drops quickly and then stabilizes until it reaches 3.2V; 0.8V per cell. There is no usable battery life beyond this point.

Figure 4 shows efficiency exceeding 85%. The diode and LT1270 switch are the two main loss elements. The Schottky diode introduces a relatively constant 7% loss, while the LT1270 switch loss varies with battery voltage. As battery voltage decreases, switch current and duty cycle increase. This has a dramatic effect on switch loss, because switch loss is proportional to the square of switch current multiplied by duty cycle. Therefore, at low input voltages efficiency is degraded because this loss is a higher percentage of the battery power drain.

If lower output current is desired, an LT1170, LT1171, or LT1172 can be used.

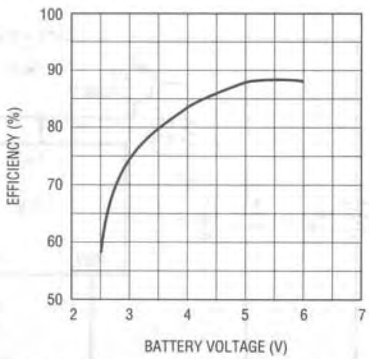


Figure 4. Efficiency for Various Battery Voltages

For literature on Switching Regulators, Call **(800) 637-5545**. For applications help, call (408) 432-1900, Ext. 456