Battery Back-Up Utilizing Low Threshold MOSFETs

Introduction

The simple battery backup circuit shown in Figure 1 utilizes Supertex low threshold DMOS devices to achieve excellent efficiency.

In fact, one of the main reasons why MOSFETs are gaining popularity is that very low voltage drops, which surpass the performance of various kinds of diodes and bipolar transistors, can be achieved. Many other benefits of low gate threshold MOSFETs are explained in the text.

Circuit Description and Operation

The battery backup circuit has two modes:

1) Battery charging, and

2) Battery backup.

1) Battery charging mode

The 120VAC is stepped down via transformer and full-wave rectified by D_1, D_2, and C_1 to 7.5VDC. This 7.5VDC supplies power to RL as well as providing the charging current to the batteries. R_1, D_3, and D_4 generate a 1.2V reference for U1a and U1b. D_5, R_2, R_3, C_2, and COMP2 keep Q_1 and Q_2 off when switch S is closed. The battery, consisting of 5 nickel cadmium cells in series, is being charged with a current set by R_8 and the intrinsic drain to source diode of Q_2. For fully discharged batteries, there will be a high charge current for a few seconds, rapidly decaying to a slow charge.

As the battery becomes almost fully charged to 6.8V, the current is reduced to a trickle charge current of a few milliamperes. The trickle charge current is further reduced to microamperes when V_{BATT} exceeds 7.0V. This is because the voltage across the diode of Q2 is 0.5V and will allow only a small amount of current flow. This maintains full charge of the battery, when not in use, over an extended period of operation.

2) Battery backup mode

When switch S is opened, simulating power outage, unplugged equipment, or blown fuse, the circuit goes into battery backup mode. U1b turns on Q_1 and Q_2. As V_{BATT} supplies the 60Ω load, U1a monitors the V_{BATT} voltage keeping it from fully discharging, as complete discharge and subsequent cell voltage reversal can degrade the performance of the NiCd battery. The circuit is designed for the U1a to turn Q_1 and Q_2 off if V_{BATT} is less than 5.5V and on if greater than 6.5V. The hysteresis is designed to avoid oscillation and is set by R_4, R_5, R_6, and R_7.

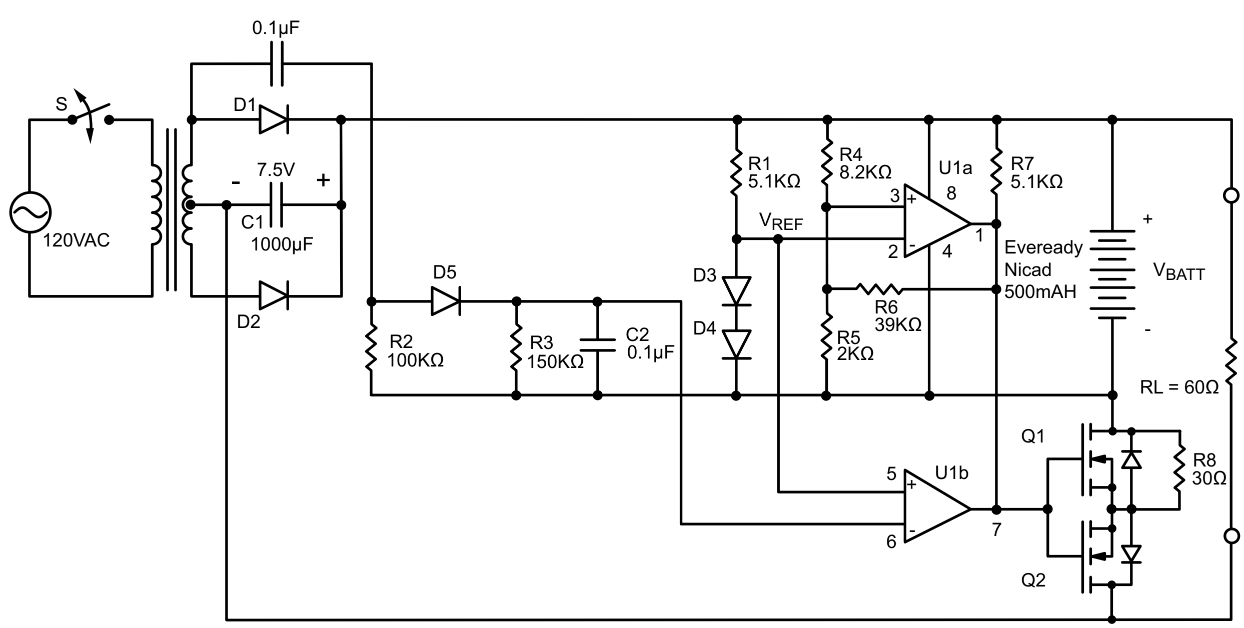

Figure 1. Battery Back-up Circuit

Design Considerations and Component Selection

The design of this circuit utilizes standard, readily available components. The number and different types of components are minimized. Diodes D_1 to D_5 are 1N4001. All resistors are standard 1/4 watt, 5% tolerance. National Semiconductor's dual comparator LM393N is used for its low biasing current for U1. The battery consists of 5 Eveready nickel cadmium cells in series. The cells are AA size, CH15 with a C rating of 500 mAH.

The most important factor to be considered in the design is the selection of the MOSFETs Q_1 and Q_2, which are configured as an analog switch. In the battery backup mode, the voltage drop across the MOSFETs must be low to minimize resistive voltage drop and power loss, consequently enhancing battery life.

Supertex TN0604N3, low threshold N-channel DMOS transistors, are selected for their guaranteed low on-resistance at low gate drive. Another aspect considered was their cost-effective TO-92 package, which saves board space.

Device	Typical $R_{DS(ON)}$	Maximum $R_{DS(ON)}$	Test Conditions
TN0604N3	0.9Ω	1.5Ω	V_{GS} = 5V, I_D = 750mA
	0.6Ω	0.75Ω	V_{GS} = 10V, I_D = 1.5A

Q_1 and Q_2 are easily turned on with a simple pull-up resistor, R_7. For a "worst case" design, $R_{DS(ON)}$ = 1.5Ω and a load current of 125mA are used. Maximum voltage drop across Q_1 and Q_2 works out to only 375mV. In actual operation, this voltage drop is substantially lower because the typical value of $R_{DS(ON)}$ is 0.8Ω. The voltage drop across Q_1 and Q_2 was measured to be 200 mV.

Figure 2 is a discharge curve of V_{BATT} vs Time showing battery backup operation of approximately 4 hours. Figure 3 is a charge curve of the battery.

The component selection ensured that basic charging current guidelines for Nicad cells were not violated. Assuming the worst case, using fully discharged batteries, the maximum charging current will be 227mA.

$$\frac{\text{Rectified D.C. voltage - diode drop}}{R8} = \frac{7.5 - 0.7}{30} = 227mA$$

This current will last only for a few seconds, and is completely safe for the battery as well as Q_2.

In the charging mode, the battery voltage will be between 6.5 to 6.7V for the majority of the time. The charging current will be from:

$$\frac{7.5 - 6.5 - 0.7}{30} = 10mA \text{ to } \frac{7.5 - 6.7 - 0.7}{30} = 3.3mA$$

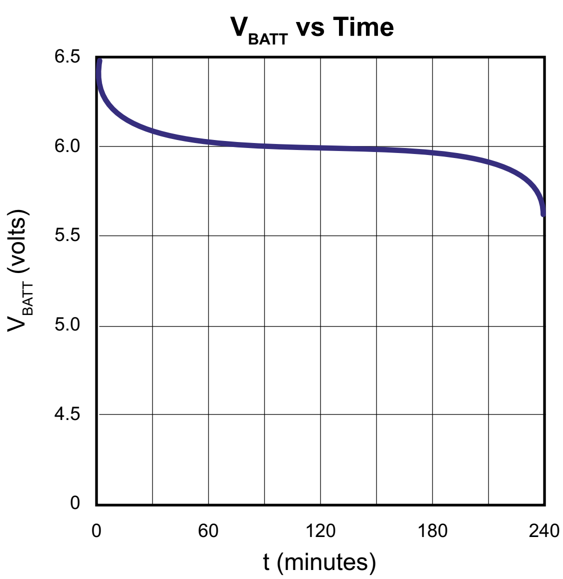

Figure 2. V_{BATT} Discharge Curve

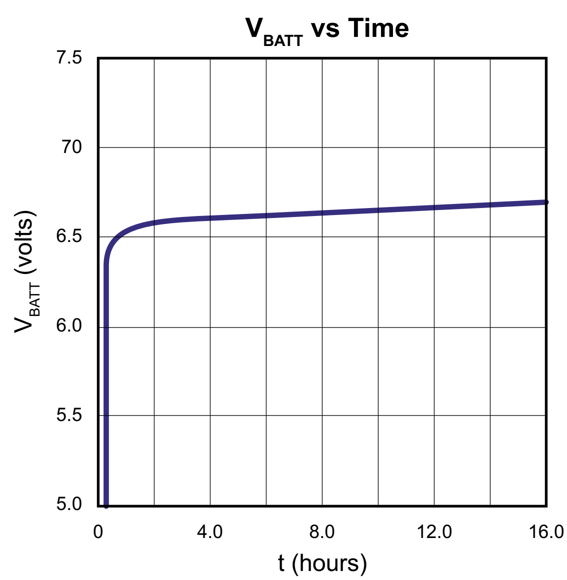

Figure 3. V_{BATT} Charge Curve

The charge rate will be from:

$$\frac{10mA}{500mAH} = 0.02C \text{ to } \frac{3.3mA}{500mAH} = 0.007C$$

which is very safe for the Nicad cells.

Optional Features

When space is at a premium, Supertex's TN2504N8 provides performance almost identical to TN0604N3, in the SOT-89 (TO-243AA) surface mount package.

Added features such as battery backup mode indicator, low battery voltage early warning, or battery shutdown indicator can be incorporated by using one or more of the optional circuits shown in Figure 4A through 4C. These can be easily modified to interface with a microprocessor in more complex systems.

Nickel cadmium batteries are quite rugged. However, they are prone to damage due to cell voltage reversal if fully discharged. Other kinds of batteries are more sensitive, and may be damaged below a certain voltage per cell, e.g., 1.75V for lead acid.

The circuits shown can be modified to suit other kinds of rechargeable batteries, e.g. lead acid, lead calcium (gel), lithium, etc. For lead acid, the threshold voltage, to disconnect the load from the battery can be adjusted to 1.75 volt per cell.

Conclusion

Very low drain to source voltage drops can be achieved with MOSFETs. Bipolar transistor performance is limited by V_{CE}(sat) and diodes by V_F , depending upon the semiconductor material used. This circuit utilized the following features of MOSFETs:

1. Low drain to source voltage drop.
2. Complete turn-on/off of bidirectional currents.
3. Turn-on with low biasing voltages.
4. No biasing power compared to base current loss in bipolar transistors.
5. Utilization of the intrinsic drain to source diode for limiting charging currents to efficient and safe levels.

The battery backup circuit described demonstrates the benefits of Supertex N-channel low gate threshold devices. These are available in either surface mount (TN2504N8) or TO-92 (TN0604N3) packages. These are ideally suited for battery powered applications. Very often, circuit designs require low on resistance to prolong battery life, low gate drive to meet battery voltage limitations, and small packages to accommodate board space limitations. The Supertex low threshold DMOS discrete transistor family were designed to satisfy such requirements.

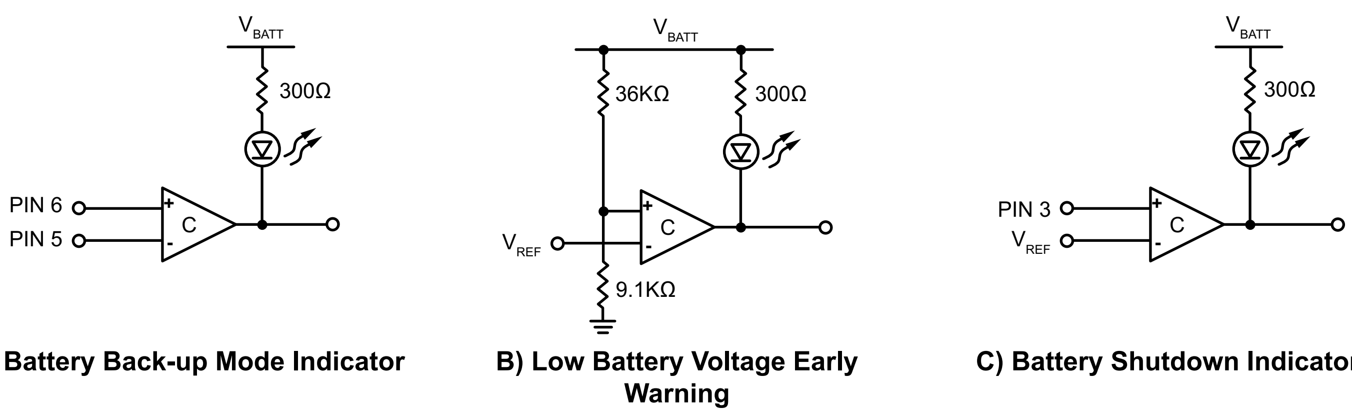

Figure 4. Optional Circuitry

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