TECHtips

Electronics Manufacturing Insights from ACI Technologies, Inc.

Identifying Battery Load Qualification Test Parameters

In a previous Tech Tip (see *Battery Selection for Electronic Systems*), considerations were discussed for selecting an appropriate battery for an application. After selection, testing should be performed to confirm that the battery can provide the power required for the specific application. Some battery definitions should be understood when discussing power load qualification testing of batteries.

Definitions

Cell: Electro-chemical unit consisting of at least one anode and one cathode. The cell voltage is the voltage potential between the anode and cathode material.

Cell Element: One or more cells wired in parallel.

Battery: One or more cells (elements) wired in series. The battery *voltage is the total voltage of each cell element.*

Cell Numbers in a Battery: Cells in a battery are numbered starting at the negative side of the battery. For example, Cell 2 is the second cell from the negative end of the battery.

Primary Battery: Battery that is disposed after a single use. A primary battery is not designed to be recharged.

Secondary Battery: A secondary battery can be charged after use. These batteries are also called "rechargeable" batteries.

Run Time: Time it takes to discharge a fully charged battery.

Cycle: A single discharge followed by a single charge of a secondary battery.

Cycle Life: Cycle life is the number of cycles until the discharged capacity is less than 80 percent of the capacity in the manufacturer's specification, or the capacity when the battery is new.

Simple Capacity Discharge Test: Constant current discharge to minimum discharge voltage.

Typical Run Time Discharge Test: Discharge a fully charged battery under the application load and record the time when the battery reaches the minimum voltage.

Cell String: "Cell string" or "cell stack" is another term for a battery with one set of cells wired in series. Some high reliability battery designs may have parallel sets of cells wired in series (essentially multiple batteries wired in parallel). An individual battery in this type of set up is sometimes referred to as a "cell string." This type of redundant battery design is useful if one cell string fails, but the device can operate with the lower capacity and current rate capability of the remaining cell string(s).

Cell Element Capacity is equal to the number of cells wired in parallel times the capacity of an individual pack. The unit of capacity is ampere-hours. Selecting cells with similar capacities for cell elements is recommended.

Battery Capacity is equal to the lowest capacity cell element in the battery. (Capacity is not additive when cells are wired in series.) The lowest capacity cell works the hardest in a battery and as a result it will reach end of life before the other battery cells. Individual battery cells should have near identical (matched) capacities. If resources are not available for testing and matching cells, then cells should be selected from the same manufacturer with the same lot number.

C-rate: The battery capacity is listed in the battery manufacturer's specification and C-rate is generally defined as the current it takes to discharge a fully charged battery or cell in one hour. For example, the 0.5C rate means the cell will take two hours for a full discharge. A C-rate discharge for low current rate, long run time batteries can be misleading. Light weight batteries designed for long runtimes typically have sacrificed high current discharge capability for the long run times and are not capable of discharging their full capacity in one hour.

Figure 1: BT2000 allows for the characterization of various battery attributes such as charge and discharge capacity.

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Initial load qualification testing may be as simple as installing battery cells in an electronic device, such as an alarm clock or flashlight, and checking that the device performs as expected and the device runs for the expected time. This “quick and dirty” type of testing may be adequate as an initial test for non-mission critical applications that draw constant current.

For high reliability applications and applications with variable power loads, load qualification testing is more complicated and a test plan should be made. The engineer should characterize the power requirements (Figure 1) of the electronic device and the operating voltage range. The maximum and minimum current rates should be identified along with the time spent at the different current rates. The required run time before battery replacement or battery charge should be identified. If the device will be switched off and stored several times before battery charge or replacement, this too should be noted. Typically, during standby mode, the device will have low current draw. During high power load, it is important to estimate time and current of the current load.

Next, the current should be plotted against time to create an estimated current load profile for the application (Figure 2). If the device will be shut off and stored prior to replacing or charging the battery, the current profile should include half hour to one hour rest periods with no current load (open circuit) to simulate off times. Since batteries produce current by chemical reactions, during open circuit periods, the battery “rests” and reaches a new electro-chemical equilibrium. The open circuit voltage will gradually rise until the new equilibrium is established. After the open circuit rest, the battery may be able to handle higher current rates than at the start of the open circuit. The new equilibrium also allows the battery to discharge additional capacity available from the total theoretical capacity of the electrode materials. Typically the new equilibrium is fully established within a half hour.

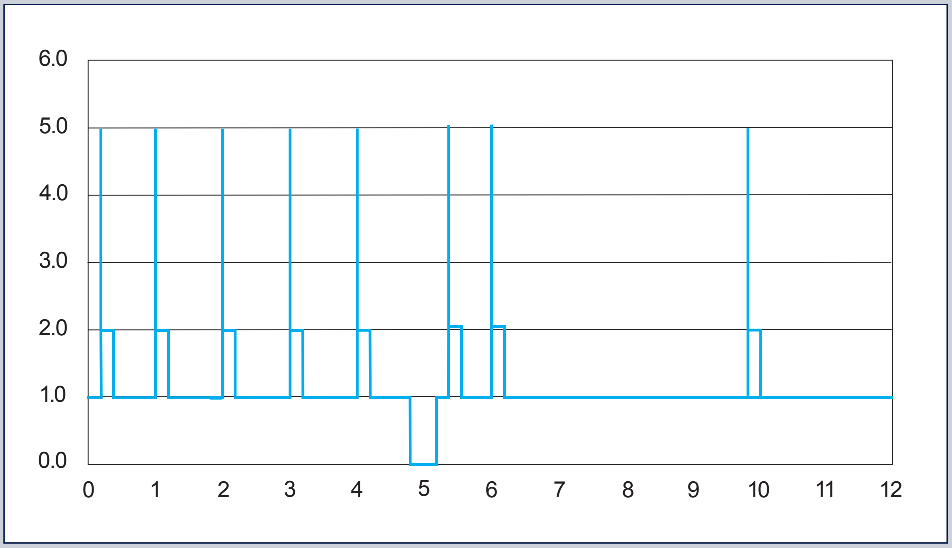

Figure 2: Typical current load profile for batteries.

Another consideration for the test plan should be the timing of high current rate discharge loads. A fully charged battery can tolerate short duration high rate discharge current better than batteries with low state of charge (SOC). For example, a current load profile for typical device use may have high current rate discharges only when the battery is at high SOC. If on rare occasions, a high rate current is required at low battery capacity, then include a high rate current discharge when 80 to 90 percent of the rated capacity has been discharged.

The test plan should include testing at the low and high temperature extremes the device may experience, as well as at room temperature. A battery discharged at its low temperature specification will have shorter run time and poorer high current rate performance than a warm battery. This performance degradation is because chemical reactions occur more slowly at low temperatures. Repeated discharge at high temperatures may shorten the cycle life while storage at elevated temperatures can shorten the shelf life of the battery.

Qualification load testing should occur prior to finalizing the housing design. Preferably, the qualification testing could start as soon as the power load can be estimated from the device design. Test early in the design cycle to allow the choice of an alternative battery if the selected battery has performance issues.

ACI Technologies offers power load testing of batteries at controlled temperatures. For more information, please contact the helpline at 610.362.1320 or via email to helpline@aciusa.org.

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