# Checking Battery Health while Charging

A new tool that prompts replacement of a faded battery

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The “ready” light on a battery charger will eventually illuminate, but this does not mean “able.” There is no link between “ready” and battery performance. The amount of energy a battery can hold is measured in capacity, a value that gradually decreases with use and time. A faded battery charges quicker than a good pack because there is less to fill. Being ready first causes bad batteries to gravitate to the top, to be picked by the unsuspecting user. There is a caution: The “ready” light may give a false sense of security.


**Figure 1: The “ready” light lies**

The READY light indicates a fully charged battery, but this does not mean “able.” There is no link between “ready” and battery performance.

A new battery is rated at 100%, but few packs in the field deliver this; the acceptable bandwidth ranges from 80 to 100%. As a simple guideline, a battery on a portable device with a capacity of 100% should provide about ten hours of runtime, 80% is eight hours and 70% seven. The service life of a battery is specified in number of cycles. A lithium- and nickel-based battery deliver between 300 and 500 full discharge/charge cycles before the capacity drops to 80% when replacement is recommended.

Cycling is not the only cause of capacity loss. Storage, especially at elevated temperature, also robs capacity; excess heat can be more stressful to a battery than cycling. A partially charged Li-ion that is kept at room temperature loses about four percent of its storage capability in a year. The loss increases to about 20% when stored at full charge. This occurs when keeping a laptop plugged into the main. (Laptop batteries are known to have a short life.) Table 2 shows capacity retention of lead-, nickel- and lithium-based batteries at different storage temperatures.

| Temperature | **Lead acid** at full charge | **Nickel-based** at any charge | **Lithium-ion** (Li-cobalt) | |
|---|---|---|---|---|
| | | | 40% charge | 100% charge |
| **0°C** | 97% | 99% | 98% | 94% |
| **25°C** | 90% | 97% | 96% | 80% |
| **40°C** | 62% | 95% | 85% | 65% |
| **60°C** | 38% (after 6 months) | 70% | 75% | 60% (after 3 months) |

**Table 2: Recoverable capacity after one year of storage.** Elevated temperature hastens permanent capacity loss. Charge level also affects Li-ion. Store Li-ion cool and at partial charge.

Internal battery resistance also plays an important role in battery performance. Applying a heavy load on a battery with elevated resistance causes the voltage to collapse. This ends the runtime before the capacity is depleted. Rising resistance with age is common with nickel-based and early Li-ion batteries.

The modern Li-ion no longer exhibits this problem. The resistance stays low and the end-of-battery-life is solely determined by capacity. Capacity becomes the leading health indicator of most batteries. Figure 3 illustrates the fading capacity of modern Li-ion against a steady low resistance. Improvements in Li-ion occurred around 2005; the same test on an older Li-ion would show a rise in resistance and likely cross the capacity line.

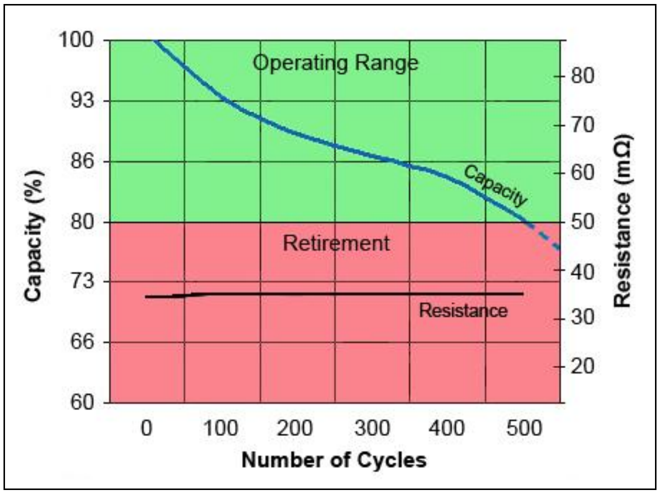


**Figure 3: Aging Li-ion battery**

Batteries begin fading from the day of manufacture. Batteries should be replaced when the capacity drops to 80%.

Courtesy of Cadex

Lead acid batteries also keep low resistance with decreasing capacity. A starter battery cranks well until one morning lack of capacity prevent turning the motor. (Older starter batteries may run at less than 20% capacity but still start the motor well.) Most battery testers only measure voltage and internal resistance; the capacity remains unknown. The end-of-battery-life often comes as a surprise.

Equipment manufacturers base the runtime of a device on a new battery with 100% capacity, but this can only be achieved in the first year or so. Realizing the difficulty to measure capacity, the medical industry often relies on date-stamping to prompt battery replacement. With heavy use, the capacity could fade sooner than the mandated two years, but most modern batteries last much longer. Date-stamping causes many good batteries to be replaced too soon, increasing operational cost and stressing the environment.

“Smart” batteries with SMBus come to the rescue by recording the cycle count and advising replacement after a given number has been delivered. But this technology comes with baggage as well. Smart batteries need periodic calibration to maintain accuracy. The largest limitation, however, is its inability to reveal capacity; the fuel gauge only indicates state-of-charge. This means that a battery that has dropped to 50% capacity will still show 100% charge. The result is a runtime that has been cut in half. SMBus batteries are found in portable computing, medical and military devices.

Public safety organizations often use the battery until it stops dead. Failures almost always occur at the most awkward time during heavy traffic or in an emergency. Battery analyzers can prevent this from happening. Attaching a removable label to a battery indicating service date, due date and capacity offers a simple and self-governing way to manage a battery fleet. With this information on hand, prudent battery users only pick a pack that has recently been serviced. Expired units are removed, run on the battery analyzer and are relabelled. The setting up is simple and managing the system requires only about 30 minutes per day. Figure 4 shows a label printed on the Cadex C7000 Series battery maintenance system.

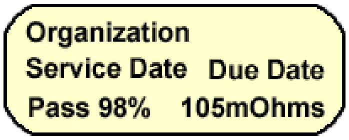


**Figure 4: Sample of removable battery label**

The label printed by a Cadex battery maintenance system shows the name of the organization, service dates, battery status, capacity and internal resistance.

Conventional battery analyzers measure the capacity with a full discharge, but there is a need for faster test methods. Rapid-testing has been offered and the accuracy varies according to the method used. Early devices linked battery state-of-health (SoH) with internal resistance. While this may still be effective for nickel-based batteries, the steady low resistance of the modern Li-ion renders this method obsolete.

New technologies by Cadex look at the mobility of ion flow between the electrodes. HealthTest™ uses *electrochemical dynamic response* to estimate battery SoH. The test takes 30 seconds, provides a 90–95% correct prediction and services batteries with a state-of-charge from 40–100%.

The next step is incorporating the HealthTest™ engine in a charger, and Cadex is developing such a device. When the "ready" light on this charger illuminates, the user is assured that the battery is fully charged and has a capacity of 80–100 percent. A faded battery with a low capacity or other anomalies is given a red FAIL light, prompting replacement. Placing health validation in a charger provides quality control at no extra effort. More importantly, the system guarantees optimal use of each battery while reducing fear of unexpected power loss. Only good batteries are kept in the fleet; faded packs are shown the exit door. This saves money and protects the environment.

The HealthTest Charger™ can also check batteries on the fly. The user simply inserts the pack into the charger, presses TEST and a snapshot of the electrochemical battery is given in 30 seconds. The readings reflect the electrochemical condition of the battery independent of coulomb counting, impedance tracking and other data that may be stored in the battery.

The charger also assists in incoming inspection to verify proper function before releasing the batteries into the field. Another useful application is inventory control by evaluating unknown packs that have accumulated in boxes. Many batteries are protected with diodes and the HealthTest Charger™ can also service these, but the manual TEST is not possible. Figure 5 shows the user-interface of the charger.


**Figure 5: Panel of the HealthTest Charger**™

READY assures full charge and a capacity of 80–100 percent; FAIL prompts replacement. The TEST function serves as a quick health check on the fly.



## About the Author

Isidor Buchmann is the founder and CEO of Cadex Electronics Inc. For three decades, Buchmann has studied the behavior of rechargeable batteries in practical, everyday applications, has written award-winning articles including the best-selling book "Batteries in a Portable World," now in its third edition. Cadex specializes in the design and manufacturing of battery chargers, analyzers and monitoring devices. For more information on batteries, visit www.batteryuniversity.com; product information is on www.cadex.com.