



During a fast charge cycle, a constant current is applied to the battery while allowing the battery voltage to rise to the level required (within limits) to force this current. As the battery accepts charge, the battery voltage and temperature slowly rise. As the battery approaches full charge, the voltage rises faster, reaches a peak, then begins to drop ( $-\Delta V$ ); at the same time, the battery temperature begins to quickly rise ( $\Delta T/\Delta t$ ). Most fast or quick charge termination methods use one or both of these conditions to end the charge cycle.

### Complete 4-Cell NiMH Battery Charger

Figure 1 shows a fast, 2A charger featuring the high efficiency LTC4011 550kHz synchronous buck converter. The LTC4011 simplifies charger design by integrating all of the features needed to charge Ni-based batteries, including constant current control circuitry, charge termination, automatic trickle and top off charge, automatic recharge, programmable timer, PowerPath control and multiple status outputs. Such a high level of integration lowers the component count, enabling a complete charger to occupy less than 4cm<sup>2</sup> of board area.

Initial battery qualification verifies that sufficient input voltage is present for charging and that the battery voltage and battery temperature are within an acceptable range before charging at full current. For deeply discharged batteries, a low current trickle charge is applied to raise the battery voltage to an appropriate level before applying full charge current. When qualification is complete, the full programmed constant-current begins.

### Standalone Charge Termination

The charge termination methods used by the LTC4010 and LTC4011 utilize battery voltage and battery temperature changes to reliably indicate when full charge is reached as a function of the charge current selected. The charge current must be sufficiently high (between 0.5C and 2C) for the battery to exhibit the voltage and temperature profile required for proper charge termination. Figure 2 shows a typical fast-charge profile displaying charge current, battery temperature and per cell voltage. This profile indicates that the charge cycle terminated due to the rate of temperature rise or  $\Delta T/\Delta t$ .

The  $-\Delta V$  charge termination algorithm begins shortly after the full charge current starts flowing. A fixed delay time prevents false termination due to battery voltage fluctuations from batteries that are deeply discharged or haven't been charged recently. For batteries that are near full charge, the  $-\Delta V$  termination sequence begins immediately to prevent overcharging.

During the charge cycle, both the  $-\Delta V$  and  $\Delta T/\Delta t$  termination methods are active. For NiMH batteries, the  $-\Delta V$  termination requires that the single cell battery voltage drop 10mV from the peak voltage or the rate-of-temperature rise ( $\Delta T/\Delta t$ ) be greater than 1°C/minute. The measurements are taken every 30 seconds and the results must be consistent for four measurements for termination to take place. Typically the  $\Delta T/\Delta t$  termination method occurs earlier in the charge cycle. If this occurs, the LTC4010/4011 adds a top-off charge at a reduced charge current for 1/3 of the programmed time. Top-off only occurs when charging NiMH batteries.

After the charge cycle has ended, the charger continues monitoring the battery voltage. If the voltage drops below a fixed threshold level, due to an external load on the battery or self-discharge, a new charge cycle begins with the charge termination algorithms immediately enabled.

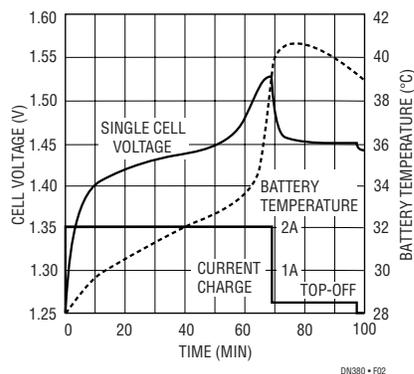


Figure 2. Typical NiMH Fast Charge Profile

### Conclusion

The LTC4010 and LTC4011 provide complete standalone solutions for reliable, robust and safe fast charging of NiCd and NiMH batteries. Proper charging is critical to not only obtain maximum battery capacity but to also avoid high temperatures, overcharge and other conditions which adversely affect battery life.

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