NiMH Battery Charging Algorithm

The Schaffler battery charger is a highly sophisticated device with a software controlled charging algorithm for NiMH batteries which includes several stages for optimising battery performance, availability and safety. All parameters are fully configurable to be optimized for each application. The charger has dual outputs to supply a standing load while accurately charging a connected battery string.

1. Initial boost charge stage:

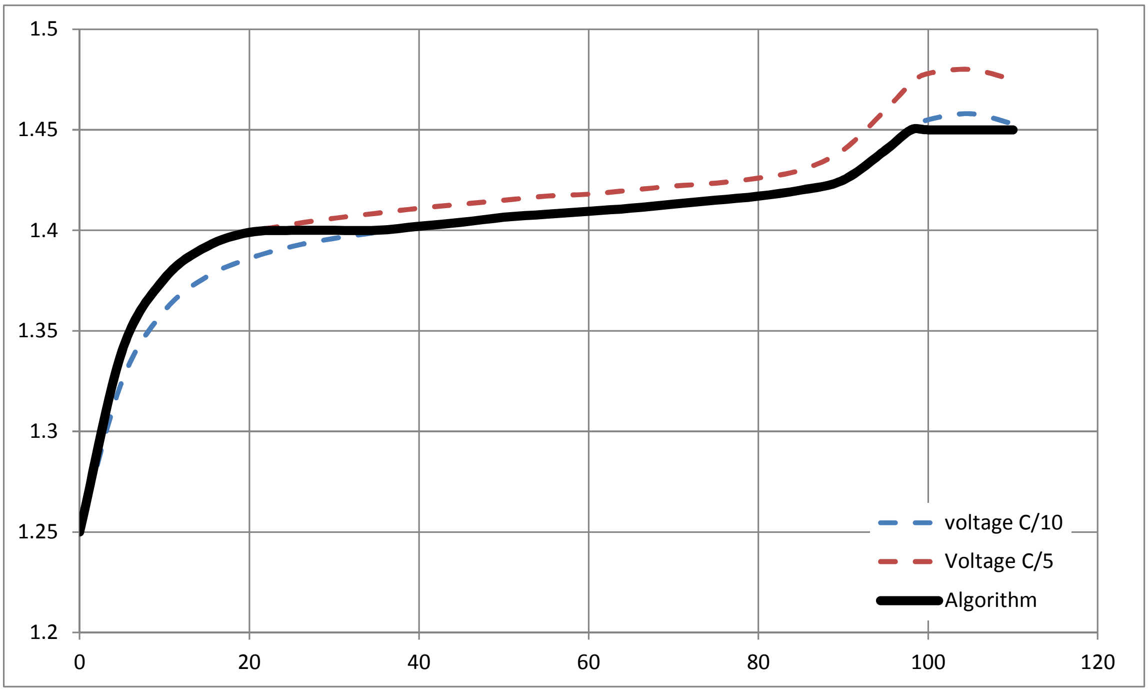
At the start of any charging cycle, a constant current of 20% of the battery capacity (0.2C or C/5) is applied to the battery string. The battery voltage follows the red dashed line for C/5 (see graph below).

When the battery voltage reaches 1.4V/cell, the voltage is limited at this value, and the current will decay from C/5 and drop to C/10 in a few minutes. This stage is terminated when the battery current reaches C/10.

The trigger voltage of 1.4V/cell is far below the maximum terminal voltage for any battery in fully charged condition and ambient temperature. There is therefore zero danger of overcharging.

This stage has the advantage that it will quickly recharge the battery string if deeply discharged, with no danger of overcharging involved. Approximately 40% of charge is quickly available to the application in a very short time.

If a battery has already more charge than the amount that this boost stage injects, the boost stage will be terminated immediately due to the terminal voltage reaching 1.4V/cell as soon as the current is applied to the battery. Overcharging is impossible even for continuously repeated cycles.



2. Main charging stage:

When the battery terminal voltage reaches 1.4V/cell during the boost charge stage and the current has decayed to C/10, the next stage, the main charging stage, commences. During this cycle, the battery is charged with a constant current of 0.1C or C/10. The battery terminal voltage is allowed to rise beyond 1.4V/cell. The battery will follow the C/10 charging curve during which the voltage slowly rises (see dashed blue line in the graph).

Under normal conditions, when the battery voltage reaches 1.45V/cell, the voltage is held constant at this value while the current decays down from C/10. When the current reaches C/20, the stage is ended.

This stage has the advantage that the main charging current is terminated slightly before 100% capacity. The current is allowed to decay to lower value while the voltage is held constant. This technique ensures the battery gets charged to 100% capacity, and allows cell balancing with no detrimental effects.

When the battery nears the fully charged condition, the voltage rises more rapidly while the cell temperature and pressure rises quickly. If left to continue, the cell voltage will reach a maximum and then begin to fall again. Temperature and pressure may lead to gas venting. The Schaffler algorithm is designed to terminate this stage of the recharging cycle before this condition is reached, ensuring maximum battery life.

The Schaffler algorithm has four terminating triggers to prevent over-charging:

a) Maximum voltage of 1.45V/cell, temperature compensated at -3mV/cell:

Battery voltage is continuously measured and the charge stage terminated when the cell voltage reaches 1.45V/cell, temperature compensated at -3mV/cell. This is the normally used trigger for ending the charge cycle.

b) Maximum time of 10 hours:

If none of the charge termination triggers are detected, the cycle will end at a maximum of 10 hours. Even if a near full battery misses all of its termination triggers, the maximum time limit will ensure that the battery will not suffer significant damage, especially since the charging current is only C/10.

c) Negative battery voltage slope:

If the battery terminal voltage falls due to it having reached full state of charge and none of the other triggers have been detected, the falling terminal voltage will trigger end of charge.

d) Maximum battery temperature:

The battery temperature is monitored and if the sensor reaches the trigger temperature (typically set at 45*C), the cycle will be terminated.

3. Maintenance stage:

The maintenance stage is characterised by the terminal voltage being regulated at 1.4V/cell in combination with the charging current limited at C/200 or lower current.

It is also possible to set the current limit at zero current. This will control the charger to have zero current flowing to or from the battery, effectively applying the same condition as having an open circuit breaker in series with the battery. The charger will accurately measure and control current into/out of the battery to be effectively zero. The effect is that the charger output voltage will track the open circuit terminal voltage of the battery string, regardless of ambient temperature. The bus voltage will therefore slowly decay as the battery self-discharges.

A more beneficial maintenance condition is to allow a small positive trickle current such as C/200 or C/500 or any other value that matches to some degree the self-discharge of the battery. The bus voltage will usually be constant, chosen at a terminal voltage of 1.4V/cell, with battery temperature compensation of -3mV/*C applied to the battery charger output regulation value. The effect would be that the bus voltage will track up and down as the battery temperature falls or rises for any reason. A current limit of C/200 or smaller will ensure that the current in the battery will never reach harmful levels. Overcharging due to high ambient temperature, or thermal runaway is completely eliminated both by the temperature compensation and the low value of the current limit. The value of C/200 (or smaller) is far lower than the typical manufacturer's rated permanent endurance current of 0.05C (C/20).

4. Automatically triggered re-charging:

Since NiMH batteries tend to have significant self-discharge, especially at elevated temperature, it is important to automatically trigger the charge cycle at given time intervals or with specific conditions.

a) Main input power failed:

If the main power drops out and subsequently returns, the charger control circuits will be without power for a time and then go through the normal restarting routine. The assumption is that the battery has discharged while the power was off, so a charging cycle is always commenced after a main power off-on cycle. Typically a battery will not be completely discharged so most often the initial boost stage will be skipped and just the main stage will be applied to bring the battery back to full state of charge.

b) Main power brown-out:

Power dipped, allowing insufficient power for the charger to supply the load, resulting in partial battery discharge. If the main power dips below the undervoltage lockout value of 500V, the battery charger can not supply the load enough to prevent the battery from discharging. The charger control circuits remain active down to the ultra-low mains voltage of 150VDC, so it will detect the degree of discharge, and if beyond 1% of capacity, it will automatically start a charge cycle once power returns to normal.

c) Timer controlled:

The charger is equipped with a battery-backed-up real-time clock. The clock is used for a timing cycle to trigger a recharge cycle at a set interval. The interval is determined by expected battery self-discharge and the required available capacity. For example, if the self-discharge rate at 30*C is 1% per 24 hours, and if the specification for the battery is to have at least 90% of charge available to the load, then re-charging must be triggered automatically every 10 days if none of the other triggers were detected. This ensures that the battery is always available at a specified minimum capacity of 90% (or any value that is specified by the application).

Cell balancing:

NiMH batteries do tolerate a small amount of overcharge. If any cell or block of cells is sitting at a higher state of charge, then during charging, that cell/block will reach the full state before the entire string reaches full state. This is a sub-optimal state of affairs and a 2-terminal charger cannot actively balance cells/blocks. So what happens is, the block that reaches full state will be over-charged by a small amount before the cycle is ended. The over-charged cell will not take on any more charge but the rest of the blocks do, allowing them to catch up. So with repeated cycles, an unbalanced string of cells will reach balance.

Temperature sensing:

The Schaffler charger has provision for two PT100 temperature sensors to be connected. The highest of the two sensed temperatures is used for control. These sensors need to be placed in such a position as to sense string temperature as reliably as possible. It is not possible to measure all cells, so it is not implausible that the sensor will not pick up a block which has reached full state of charge before others. So temperature sensing is not so valuable for unbalanced strings; rather it is more aimed at sensing the average temperature of the battery string as determined by ambient temperature.