

Fast Charge Circuits for NiCad Batteries

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Safe, fast charging of NiCad batteries is attractive in many applications. Short charge time requires high current. A potential difficulty with high current charging is battery heating. Excessive internal heating degrades the battery and can cause gas venting to the outside atmosphere. Fast charge schemes based on monitoring cell voltage during charge suffer because cell voltage is not necessarily indicative of the battery's charge state. Additionally, the battery's charge-voltage relationship may alter over life and temperature. Similarly, open loop charging techniques involving high charge rates for a fixed time do not account for battery charge state or characteristic shifts over life and temperature.

One way to charge batteries without abuse is to measure cell temperature and taper the charge accordingly. This method is based on the fact that a discharged battery converts charging current to stored electrochemical energy, with relatively little heat produced. When the battery arrives at full charge the cell is saturated and cannot hold any more energy. As such, heat is produced, raising battery temperature. One way to detect this point is to measure cell surface temperature referred to ambient. An absolute temperature measurement is undesirable

because cell temperature represents the summation of excess charging energy and ambient temperature. Additionally, the ambient and battery temperatures must be measured in phase. The thermal time constant of a battery pack can easily exceed one hour. If battery temperature is referred to a quickly responding ambient temperature poor charging characteristics can result. Consider the case of a portable computer retrieved from a locked automobile on a summer day. Passenger compartment temperature can exceed 120°F. The computer is brought inside, where the ambient temperature sensor quickly settles to 73°F. The battery pack temperature is sitting at 120°F looking through a one hour thermal time constant. Under these conditions the system is fooled into believing the battery has just received a full charge, and no charge is delivered. The opposite effect occurs if the computer is in a car parked overnight in Minneapolis in January. These effects are avoidable by lagging the ambient temperature information with a time constant similar to the battery packs. Figure 1 shows a simple analog. The resistors represent thermal resistance while the capacitors correspond to thermal capacitance. Ambient temperature appears as a common mode term, while charger energy affects the battery only. Note that the ambient and battery

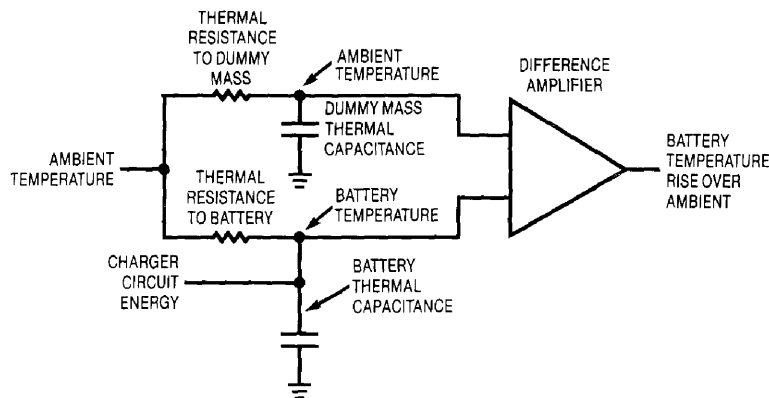


Figure 1. Simplified Thermal Analog. Matched Thermal RC Terms Provide Immunity to Ambient Temperature Shifts.

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temperatures do not require the same individual R-C values to present phased information to the difference amplifier. Rather, their RC *products* must be matched. A massive battery pack with relatively low thermal resistance to ambient can be matched by the time constant of a well insulated (e.g., high thermal resistance) small thermal mass.

Practical Thermally Based NiCad Charger

Figure 2 shows a practical circuit. Thermocouples sense cell and ambient temperatures. The LT1006 amplifier furnishes the low level capability necessary to work with the microvolt level thermocouple signals. To understand the circuit's operation, assume a discharged battery pack in the transistor collector line. The battery and ambient thermocouples are at the same temperature. The battery thermocouple is directly mounted to one of the cells in the pack. The ambient thermocouple is thermally insulated and mounted to a mass, perhaps a frame member of the equipment. Under these conditions the sensors are phase matched, their outputs cancel and A1 sees 0V. The offset adjustment deliberately introduces enough input offset for A1 to swing positively, turning on the transistor. Current flows from the supply, through the battery pack and to ground via the $250\mu\Omega$ shunt. The low impedance shunt minimizes losses, cost, and complexity. The voltage across the shunt rises to about $625\mu\text{V}$ (the amount of offset forced by the potentiometer), and the amplifier servo controls about 2.5A through the battery pack. As the battery charges, it heats. This heat is picked up by the

*See Appendix A for construction information on low resistance shunts.

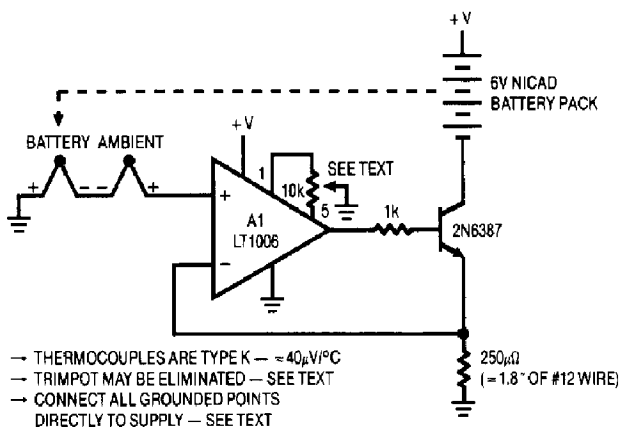


Figure 2. Thermally Controlled NiCad Battery Charger

battery-mounted thermocouple. The temperature difference between the two thermocouples determines the voltage which appears at the amplifier's positive input. As battery temperature rises, this small negative voltage (1°C difference between the thermocouples equals $40\mu\text{V}$) becomes larger. The amplifier gradually reduces the current through the battery to maintain its inputs at balance. The effect of this action is shown in Figure 3. The battery charges at a high rate until heating occurs and the circuit then tapers the charge. The values given in the circuit limit the battery surface temperature rise over ambient to about 15°C .

Figure 4's circuit is arranged for use with batteries which are committed to ground. The common emitter output necessitates exchanging amplifier input assignments, but circuit operation is identical to Figure 2. In both circuits the trimpot may be eliminated by specifying an LT1006 set at manufacture to the desired offset value.

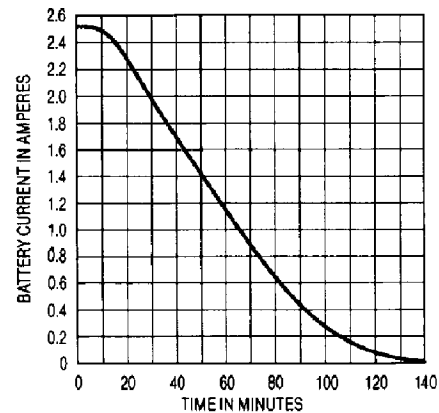


Figure 3. Figure 2's Charge Characteristics

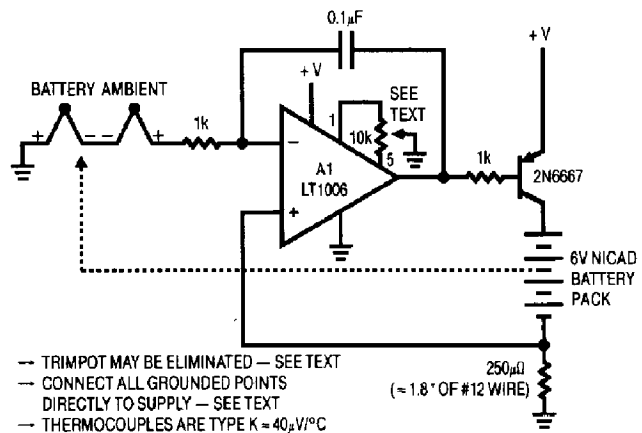


Figure 4. Figure 2's Circuit Arranged for a Grounded Battery

