HYBRID CAR BATTERY MANAGEMENT

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ABSTRACT

Hybrid cars use specific batteries, unlike electric cars. Operating modes are also different. A first set of secure operating rules is imposed by the battery manufacturer. Manufacturers also recommend measures for efficiency and reliability improvement. Design and practical construction of the vehicle generate other restrictions. An appropriate management of the hybrid car battery will avoid electrical incidents, will extend the battery lifetime and will increase performance. Based on the practical experience, included the one achieved by the activities deployed in the no.166/2007 research contract, management algorithms and considerations are presented. The algorithms are and will be implemented in electronic circuits special designed for interfacing the traction control system and diagnose and operation data loggers.

Keywords: Rechargeable battery, hybrid car, power management, battery electric parameters, management algorithms.

1. INTRODUCTION

A main component of the hybrid car is the recovery energy storage system, as buffer energy. For best results in oil based fuel consumption and exhaust gases, simultaneously with the vehicle performances increase, a sophisticated storage system is required, in its material part and also its system energy management. Regenerative energy by braking, or inefficient engine operation must be used for vehicle drive critical moments, as starting, fast acceleration, which impose a rigorous control of the storage system state.

Battery specifications and its management system depend on vehicle operation modes. Differences between vehicles determine different specifications. For small family cars, mostly used in cities, decelerations and accelerations are frequent shutting the internal combustion engine in waiting periods and energy recovery by braking significantly decrease the fuel consumption. For heavy vehicles, hybrid solution can increase the wheel torque for starting, climbing, which make possible of the use of a less power engine. For each such vehicle, a different battery and management is needed.

The right choice of the battery type and management depends on battery chemistry and electrical specifications, like energy density, internal resistance, temperature domain. Stored energy and available power are also main specifications in battery design.

2. HYBRID CAR BATTERY MANAGEMENT NECCESITY

The rechargeable battery management system is mainly a monitoring system for the battery right operation. It makes security decisions in case of dangerous situations and participates to the battery lifetime increase. Parameters, as element temperature, maximum or minimum admissible voltages, charging and discharging currents overcoming is detected by the management system which must limit or stop the battery use. Those actions can be done by the management system by itself, or by other systems which receive messages from the management system. Most batteries are heavy and big, which limits the amount of stored energy. Optimising the battery stored energy utilisation is one of the main goals of this system. It is imperative to define the battery and its best operating strategy. No matter how the electric energy is obtained – house outlet, in-vehicle generate by its main engine, or braking regenerative, the accurate estimation of the battery state, as charging state, health, operating mode, is essential for appropriate vehicle operation. The user is also interested of the battery condition and its energy level.

3. HYBRID CAR RECHARGEABLE BATTERY

For small light city vehicles, hybrid system is mostly used for starting and recovering brake. For such an application is suited o low capacity battery, small and light also, capable of high charging and discharging currents. Any battery chemistry can be used, with advantages and disadvantages, in energy density, temperature domain, internal resistance, memory, times and rates for charging and discharging, self discharge rate, protection in case of impact, possibility of series or parallel connection. Table 1 presents a parameter comparison between different battery types.

Table 1 Main battery types comparison

Parameter / **Battery Type**	Acid-Lead	NiCd	NiMH	Li	UltraCapacitor
Voltage / cell (nom.)	2	1.2	1.2	3.6	2.7
Density of energy	High	Low	Medium	High	High
Fast charge / discharge	No	Yes	Yes	Yes	Yes
Operating temperature	-20÷40 ^{O}C	-40÷60 ^{O}C	-20÷60 ^{O}C	-30÷60 ^{O}C	-40÷65 ^{O}C
Internal resistance	Low	High	Medium	Low	Low
Memory	No	Yes	No	No	No
Lifetime (cycles)	1,000	>3,000	>3,000	>1,000	>200,000
Cost	Medium	Low	Medium	High	High

Manufacturers use automotive special designed batteries, with better performances than in table 1, but usually unavailable as spare parts. For experiments, a NiMH battery was chosen. This battery consists in 3 parallel connected groups of 270 3.2Ah elements connected in series. The battery has a nominal voltage of 324V, a nominal capacity of 9.6Ah and supports up to 180A discharge current (time limited). The described battery is shown in figure 1.

4. BATTERY MANAGEMANT FUNCTIONS

Management functions are divided as: security functions, optimisation functions and display and diagnose functions. Not all this functions are achieved by any management system.

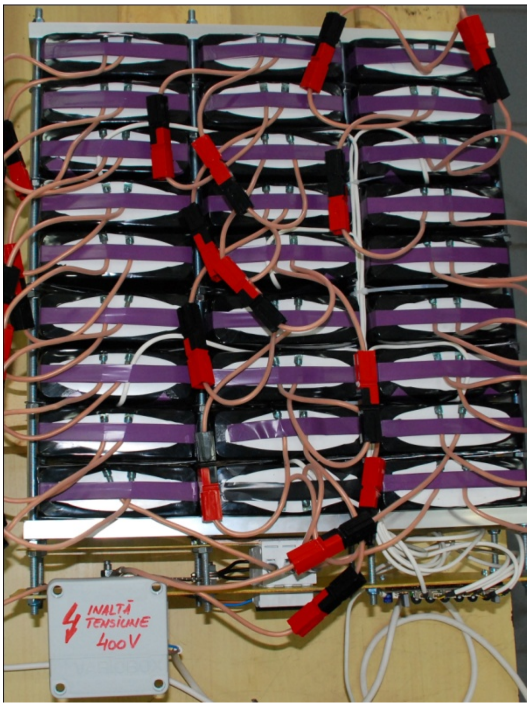

Figure 1: 324V, 9.6Ah NiMH battery

4.1 Security functions: The management system protects the battery against over-voltages, over-currents and temperature overcoming, in positive and negative ways, avoiding the battery damages. The protection thresholds are indicated by the battery manufacturer in the product datasheet. Any rechargeable battery has minimum values for discharging voltages, some batteries have maximum charging voltages (NiCd and NiMH excluded), and all of them have maximum values for charging and discharging currents and a specific temperature domain. Overcoming the imposed domains for all those parameters cause battery damages and may lead to fire hazard or explosion, affecting the entire vehicle and its passengers. Detecting the parameters exit from permitted evolution areas must cause battery disconnect from the electric network (charging on and off board and discharging on board networks) and an appropriate warning to the driver.

4.2 Optimisation functions: The management system continuously controls the electric and thermal battery base parameters (voltage, current and temperature) and computes rates of increasing and decreasing in order to predict the further evolution. Depending of computing results, preventive measures can be taken, like fans speed regulation or reducing the contribution of electric engine in wheel torque. The electric battery capacity evolution can be evaluated by integrating the charging and discharging currents, in order to smart manage the energy in the battery.

4.3 Display and diagnose functions: Those are very important functions, not only for the battery, but for the driver. An empty battery decreases the available power of the vehicle, limiting its acceleration, which is potentially dangerous. A fast change in internal battery resistance indicates battery damage. Only few messages are directed to the driver. The results of continuous measurements and calculations, including warning flags and synthetical data are logged for service and maintenance operations.

5. BATTERY MANAGEMENT

The circuitry used for battery management must implement the measurements and compute algorithms in order to accomplish system functions. Different electronic schemas are and may be designed, each one suitable for more or less functions. Two examples, designed in the research contract no.166/2007, are presented in the following.

A simple system, based on analogical and digital integrated general-purpose circuits, operates on parallel data processing, as illustrated in figure 2.

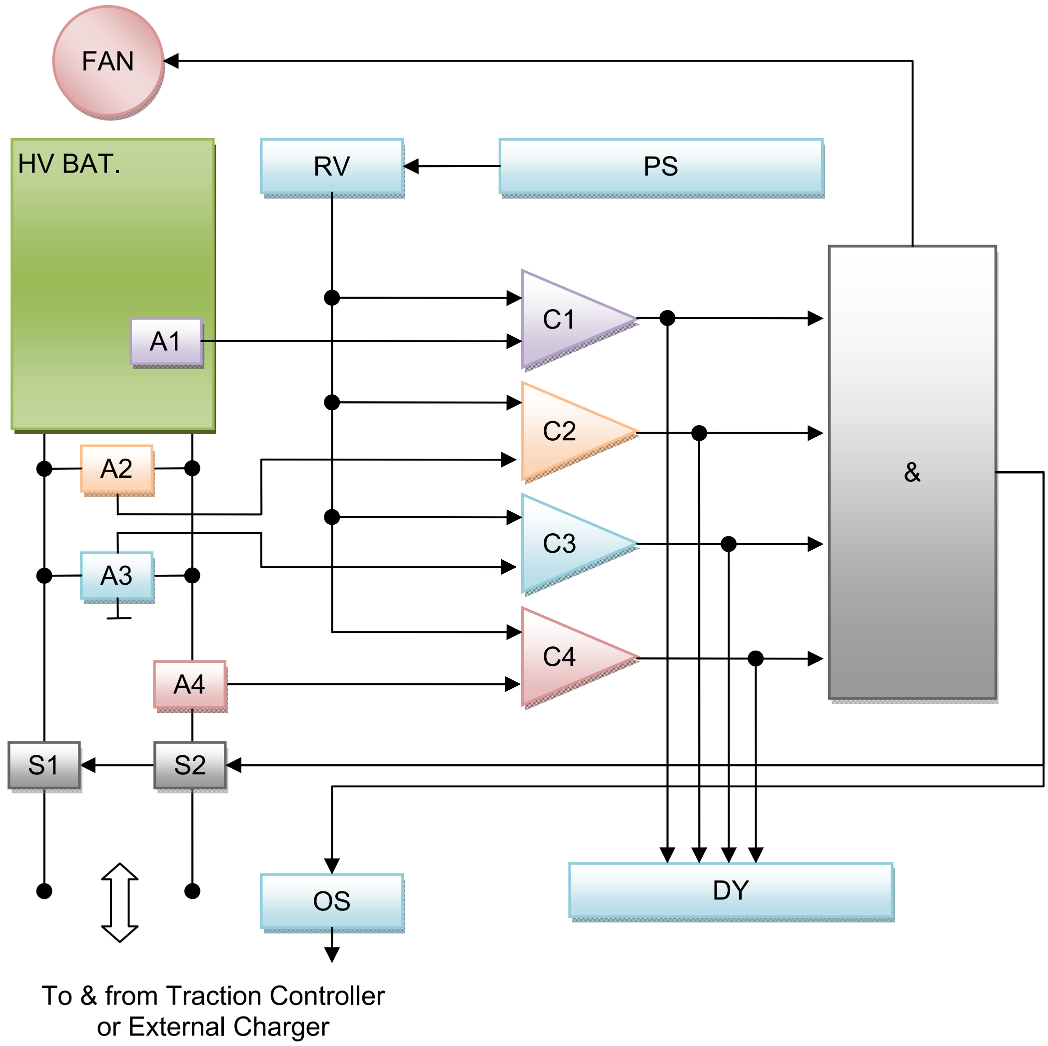

Figure 2: Block diagram of a simple battery management system

The battery management system contains several sensors: A1: temperature sensor, A2: voltage sensor, A3: insulation sensor and A4: current sensor. All the sensors convert the measured parameter in voltage. The result voltages are compared with reference values in analogical comparators: C1: temperature comparator, C2: voltage comparator, C3: insulation comparator and C4: current comparator. The digital results at comparators outputs are displayed on LED indicators and may activate a buzzer, for critical warnings. The overcoming of limit parameters disconnect the battery from the traction controller or external charger by a double switch, S1 + S2, controlled via a logical wired circuit &. Logical data may be supplied to the traction controller via an optical insulated interface OS. The whole electronic circuit is powered by a power supply unit. The power supply can be powered by the high voltage battery (HV BATT), the managed battery, or by the car 12V battery, when a galvanic insulation is required.

In fact, the battery temperature is not the same in all cells; so, there are more than one temperature sensors, which are processed separately and as mean value. The temperature comparators command the cooling battery fans too.

The comparators are often multiple comparators, because some parameters have multiple thresholds, as negative and positive (for temperature or charging versus discharging currents) and maximum and minimum (operating voltages).

The insulation processing chain measures and compares the insulation resistance between the battery outputs and the car ground (chassis). The insulation decrease may lead to dangerous situations, for the electronic circuitry in the traction controller or for the driver and service personnel.

Particular traction controllers contain the switches S1 and S2 as switch-disconnector.

It is obvious that this management system performs only security functions. The display show only information about overcoming of extreme values parameters.

A practical implementation of that system is illustrated in figure 3.

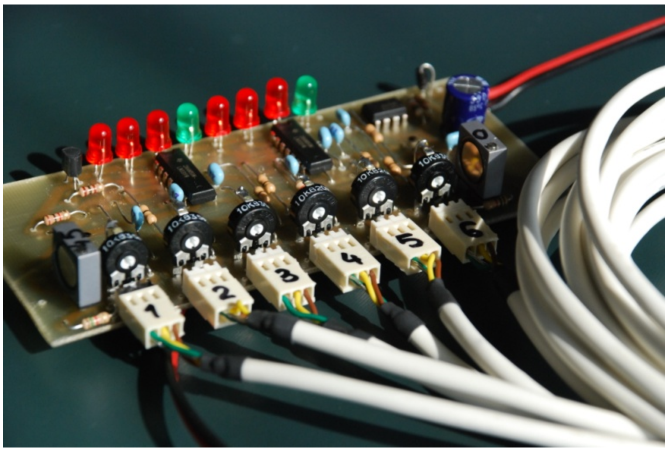

Figure 3: Photo of simple battery management system

A complex battery management system is shown in figure 4.

The sensors network is practical the same as the one used in the simple management system. The data processing is complete digital, after analogical to digital conversions, performed in the input stages of a microcontroller.

The microcontroller (μC) measures continuously and cyclically the battery parameters, as voltage, current, temperature, insulation toward the car ground. The measurements are performed with a specified time step, usually 50ms or 100ms. The measurements results are stored in a buffer memory for specific time. Lesser time step offers the possibility of mean value computing for each parameter, using buffer memory stored data, which attenuates the undesirable measurements variations due to perturbations. With these initial data, the microcontroller computes other electrical battery parameters: electrical capacity and internal resistance.

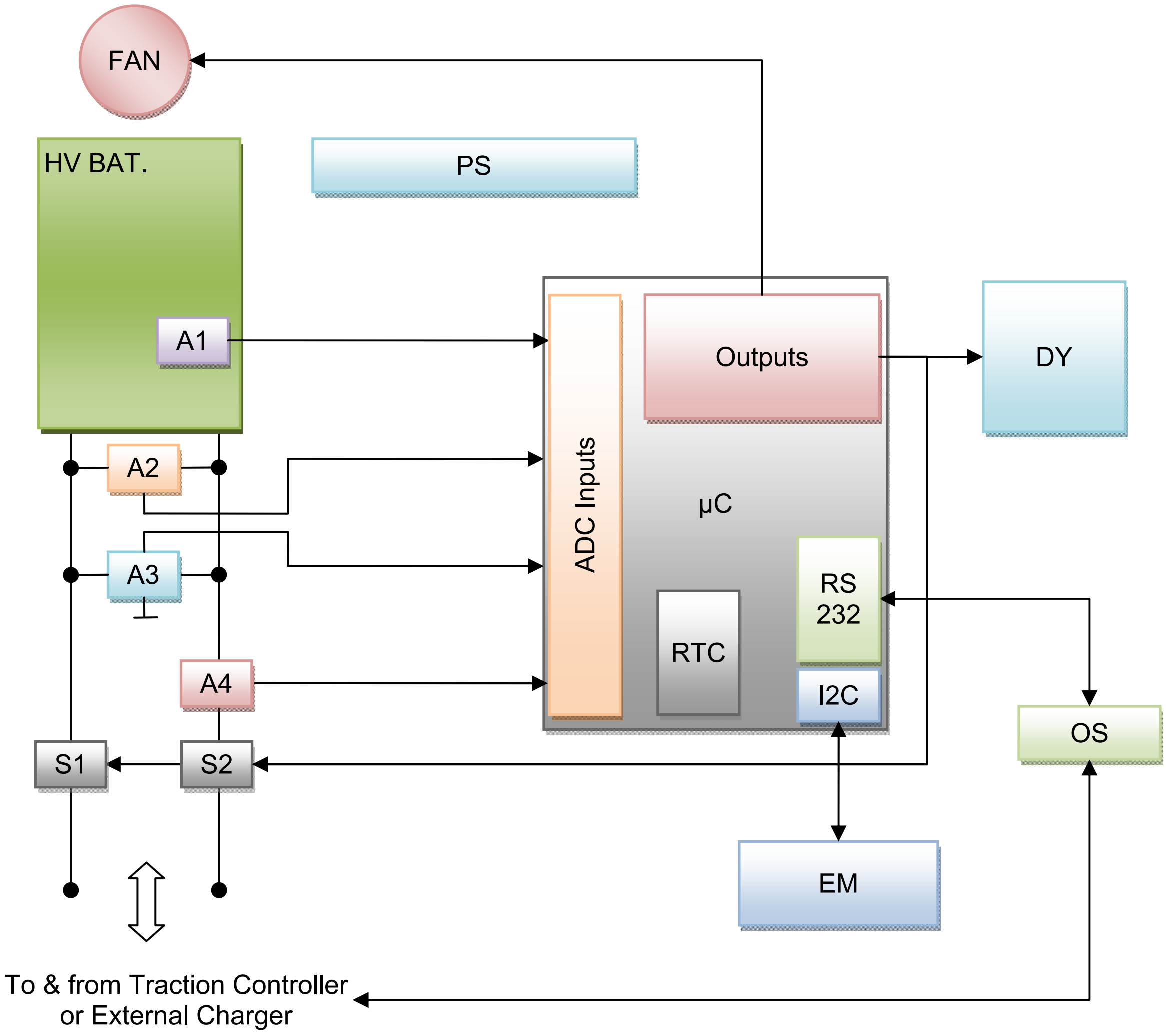

Figure 4: Block diagram of a simple battery management system

$$C[Ah](t) = \int_{t_0}^{t} i(\tau) \cdot d\tau \qquad (1)$$

$$r_{int} = \frac{\Delta u}{\Delta i} \qquad (2)$$

C[Ah](t) is the electrical capacity at time *t*, if at t_0 the battery has a known capacity. *i* is the charging or discharging current (negative for discharge). It is also possible to compute and use the loss of capacity, by changing the initial time definition. It is important to consider the battery capacity fully recovered after external charging period, as the manufacturer instructs, and use this state as re-initialisation. r_{int} is the ratio between voltage variation and current variation, using two pairs of measurements, made at different moments.

Having all these parameters, the microcontroller based system can accomplish the three function types.

The security functions results by comparing the initial parameters with pre-programmed thresholds, which can be functions of other variables: the voltage thresholds are temperature dependent and such a table of variation can be recorded in the microcontroller flash memory. A better and efficient protection is made. Supplementary, the microcontroller prepares the traction controller for the further actions by sending messages via optical insulated bus RS232.

The optimisation functions consist in informing, by bi-directional communication message – acknowledge, via the RS232 bus, the traction controller about the battery state in order to modify the charging and discharging currents, depending on the left battery capacity and its temperature, to avoid the battery disconnect due to overcoming the extreme values for the battery. The microcontroller commands the fans speed in order to minimize the consumption and the wear, and to maintain an adequate temperature. For better cooling, the fans are started at full speed when high currents in charging or discharging modes begin to be measured.

The display and diagnose functions contain data recorder in an external eeprom i2c memory, or SD-card (EM). Any message issued by the microcontroller is also stored. The recorded data is completed with the date and time, provided by the real time clock of the microcontroller. Recorded data are available to download to a laptop, using optical insulated RS232 bus, for further analyze, or can be seen on an alpha-numerical display (DY), permanently connected to the microcontroller. In normal state, the alphanumerical display shows the battery voltage, current, temperature and capacity.

This complex battery management system is part of the battery aggregate. It contains identification battery data, like battery type, initial capacity (manufacturer declared), fabrication date, serial number, service date.

A power supply is provided for the microcontroller, interfaces and sensors.

For optimal use of battery energy, when the battery current is null, the measurements rate decrease at one cycle per second, with cutting the power for all circuit except the microcontroller.

6. CONCLUSION

The fuel consumption, the exhaust gases and the hybrid vehicle manufacturing and service costs are the objectives to accomplish in design, but also the problems to manage. The battery is one of the components which have a large share in those pursuits. A battery management system can improve battery performance and increase battery life with little cost, comparative with the benefits. The complexity of the battery management system must be adapted to the traction controller requests and vehicle performance demands. The presented algorithms were designed for a NiMH rechargeable battery; bat can be modified for any other battery chemistry. In the future, battery types and management algorithms are subject to improvement, for the battery manufacturers and hybrid or electric car designers.

7. ACKNOWLEDGEMENT

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9. GLOSSARY

&: Wired logic block
A1…A4: Sensors with adaptor
ADC: Analogical to digital converter
C1…C4: Analogical comparators
DY: Display
EM: External memory
HV BAT.: High voltage battery
I2C: Communication protocol
Li: Lithium Cell
NiCd: Nickel-Cadmium Cell
NiMH: Nickel-metal hydride Cell
OS: Operating System
PS: Power Supply
RS232: Communication protocol
RTC: Real-time clock
S1, S2: Switch
μC: Microcontroller