Electronics in cars: consequences for the energy-supply system

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Abstract

The amount of electronics in cars is constantly increasing. Thus, the question arises, whether the current wiring designs will continue to be able to meet the required output related to this increase in the future. Which consequences result, then, for the design of the wiring system and its components? An examination of the electrical consumers currently installed in motor vehicles, and of those planned for future use, shows that the wiring system load during driving will increase to as much as 2000 W. Many new devices, such as the telephone, will also enjoy increasing use while the vehicle is at a standstill, which will result in the type of wiring system load changing in the future. In addition to this, loading will increase due to greater traffic density; the vehicle will be operated more often at idling speed, leading to a reduction in the available current. Thus, a balanced current supply can no longer be ensured with present designs. That means new energy supply concepts are required, e.g. the 24 V wiring system and energy management. In addition, the wiring system components must be optimized. This particularly applies to the battery, which must be further developed in order to obtain increased cell strength, a longer service life and improved temperature stability.

Introduction

The development in the automotive sector over the past several years is marked by the constant increase in the amount of electronics in the vehicle. Thus, in the early 1970s, for example, electronic ignition and mixture formation were still reserved for specialist vehicles, while today it is part of the equipment of nearly every automobile. In addition, an increasing number of vehicles are equipped with electronic control units for additional comfort and safety devices, such as air conditioning, central locking, seat heating, or ABS. The end of this development is still not in sight, for the entry of systems such as mobile telephones, navigational aids, and diagnostic facilities into the automobile has only just begun.

The growth in the range of automotive electronics is clearly reflected by its share of vehicle manufacturing costs. Figure 1 shows the development over the past several years and a prognosis. While today 16% of the manufacturing costs are spent on the electrical and electronics systems [1], the figure will be about 24% in 20 years time. The latest estimates even predict a share of marginal costs of 30%! This means the coming years will be marked by the fact that more and more functions will be carried out with electronic control

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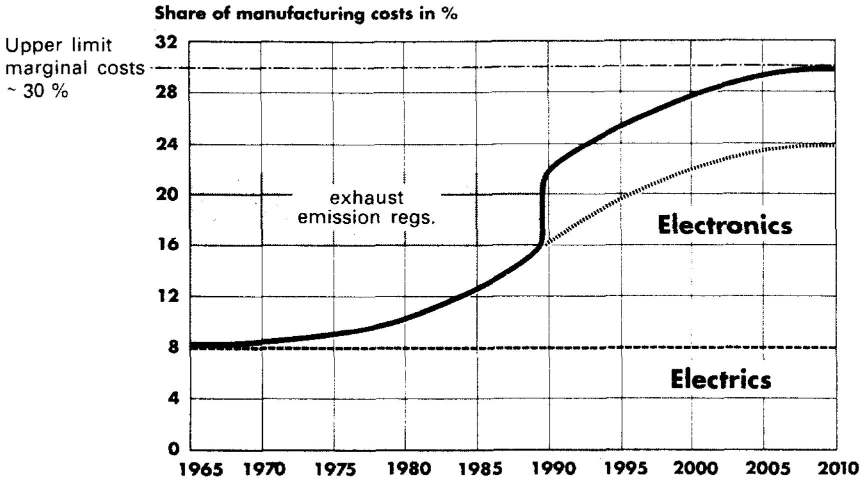

Fig. 1. Growth rate of automotive electrical/electronic systems.

units and the electric actuators controlled by them. The power requirements of these systems must be met by the wiring system. The question is, what are the consequences for the energy-supply system resulting from the growing amount of automotive electronics?

Influences on energy-supply system components

The energy-supply system of a motor vehicle is represented in highly simplified form in Fig. 2. It consists of the energy producer, the various electrical consumers, and the battery as a buffer.

The wiring system is designed so that the supply of all electrical components is ensured, even under the most unfavourable operating conditions. The following factors determine the design of the system (Fig. 3):

- the number of consumers during driving
- the number of consumers while the vehicle is stopped
- driving and traffic density
- dependability requirements

How these factors will develop in the future and what measures are necessary for a dependable supply to all consumers are discussed in the following sections.

Consumers during driving

The broad range of options offered by the vehicle manufacturers allow customers to equip their vehicles according to individual desires. This is primarily reflected in the installation of additional electrical equipment with a current consumption during driving. This must be covered by the wiring system alternator.

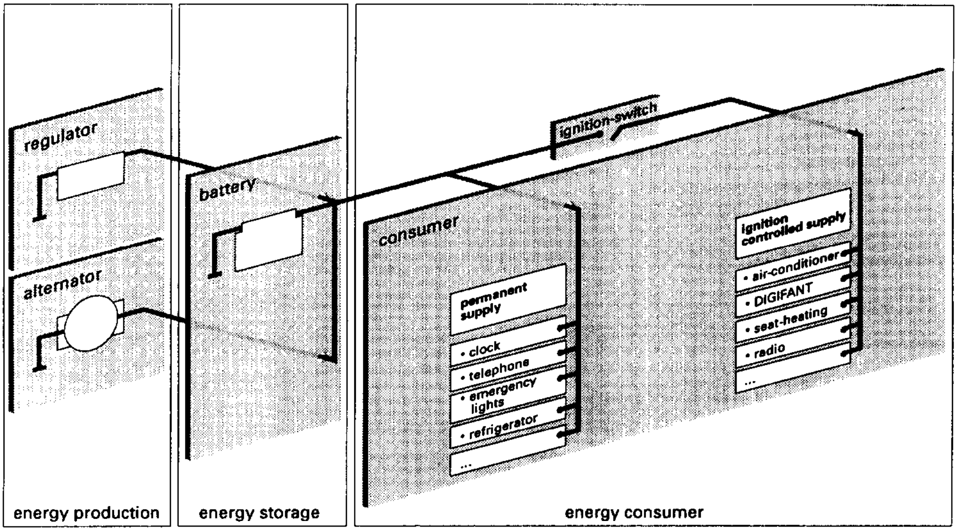

Fig. 2. Car wiring system.

The following figures are intended to illustrate the situation. The electrical consumers of a VW Passat with standard equipment have, taking into consideration the varying lengths of operation, an average power requirement of $P_{\mathrm{Basic}} = 747$ W. On vehicles with a high degree of optional equipment, the power requirement is about 50% higher, namely $P_{\mathrm{Op\text{-}Equip}} = 1132$ W, see Tables 1 and 2 [2]. These power outputs are currently made available by the wiring system, however a considerable power increase can no longer be realized with the present-day design.

Future systems, such as electric power-steering, mobile telephones and window heating, require the additional supply of up to $P_{\mathrm{add}} = 800$ W (Table

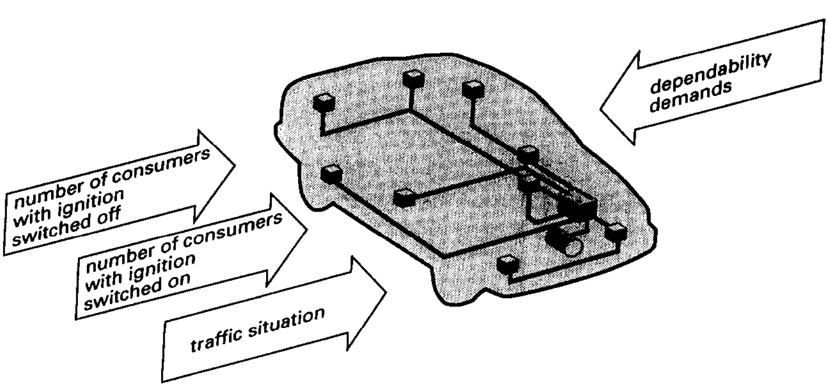

Fig. 3. Influences on wiring system design.

TABLE 1

Power requirement of basic electrical equipment

Standard equipment	Switched on period (%)	Carburettor (W)	Digifant (W)	Diesel (W)
Engine specific consumption	100	87	186	26
Dipped beam headlights	100	160	160	160
Heated rear windows	100	185	185	185
Windscreen wiper, stage 1	100	33	33	33
Fresh air/heater blower, stage 3	40	94	94	94
Radiator fan	50		50	
Limited consumers	100	33	33	33
Intake manifold preheating-hedgehog	100	260		
Glowplug system	40			250
Rear fog lights	25	6	6	6
Total consumers standard equipment		858	747	787

TABLE 2

Power requirement of a Passat with optional equipment

Optional extras	Switched on period (%)	Carburettor (W)	Digifant (W)	Diesel (W)
Fog lights	25	30	30	30
Tow-bar	30	39	90	39
Seat heating — driver	100	78	78	78
— front passenger	100	78	78	78
Air conditioner	100	72	282	83
Heated exterior mirrors	100	16	16	16
ABS	100	33	33	33
Heated washer jets	100	10	10	10

3). Here the windscreen heating, with a power requirement — depending on version — of between 700 and 1400 W, has not been taken into consideration.

This means that electrical consumers with a power requirement of up to 2000 W will be installed in future motor vehicles. This leads to the demand for high-performance alternators and batteries that are able to fulfil their function as buffers, even at peak outputs.

Consumers while the vehicle is stationary

In the past, additional equipment, such as fog lights, air conditioners or seat heaters, was primarily intended for use during driving, so that a

TABLE 3

Power requirement of future electrical consumers

Future equipment	Switched on period (%)	Consumption at $U = 13$ V (W)
Electric power-assisted steering	100	20
Self-levelling suspension		26
Heated windscreen	100	700/1400
Heated side windows	100	400
Heated rear seat	30	52
Fuel filter preheating	100	150
Water pump run-on	10	26
Electronical differential locking	100	35
Telephone (standby)	100	13
Electronically controlled accelerator		7
Reading lights	100	10
Active loudspeakers	100	20

balanced current availability was ensured with a corresponding wiring system design. Today, however, the electronic systems installed in automobiles are operated not only during driving, but increasingly also with the vehicle parked and the engine stopped. Examples of this are radios with power output stages, telecommunication systems, freezer compartments and computers. Control units that are operated in the standby mode, with the engine stopped, must also be included.

The systems must be supplied dependably by the car battery. This requires a minimization of the current consumption of devices through the use of CMOS technology and efficiency optimization. Nevertheless, there are limits here which, among other things, are also determined by the electromagnetic compatibility of the systems. For this reason, it is necessary to increase the capacity and the cycle stability of batteries in order to offer dependable operation, reliable starting characteristics and a long service life under these operating conditions.

Driving

The above considerations have been concerned exclusively with the present requirement, which will certainly also increase in coming years with the application of new technologies. Decisive for the functionability of the wiring system is the fact that this requirement is met, i.e., that a sufficiently large current supply is available. The output passed from the alternator to the wiring system is highly dependent on the rotational speed of the alternator (Fig. 4). The available current increases super-proportionally with the r.p.m.s, i.e., driving also has a considerable influence on the available current. Figure 5 represents the r.p.m. curve during city driving under poor

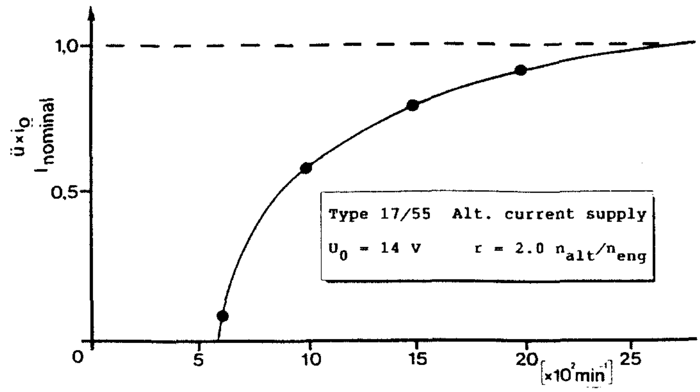

Fig. 4. Alternator performance curve.

weather conditions. This is the most unfavourable type of operation imaginable. It can be seen that the vehicle is operated at idle for about 30% of the time. At idling speed, however, the available current drops by more than 50% compared with the nominal current! Considering that, for example, on the one hand the driving distance covered by all the vehicles in the F.R.G. between 1977 and 1987 has increased by 28%, and on the other hand the available inner-city traffic area was expanded by only 9% within this period [3], then an increase in the length of idling phases is unavoidable. This means that the available current will be reduced during city driving.

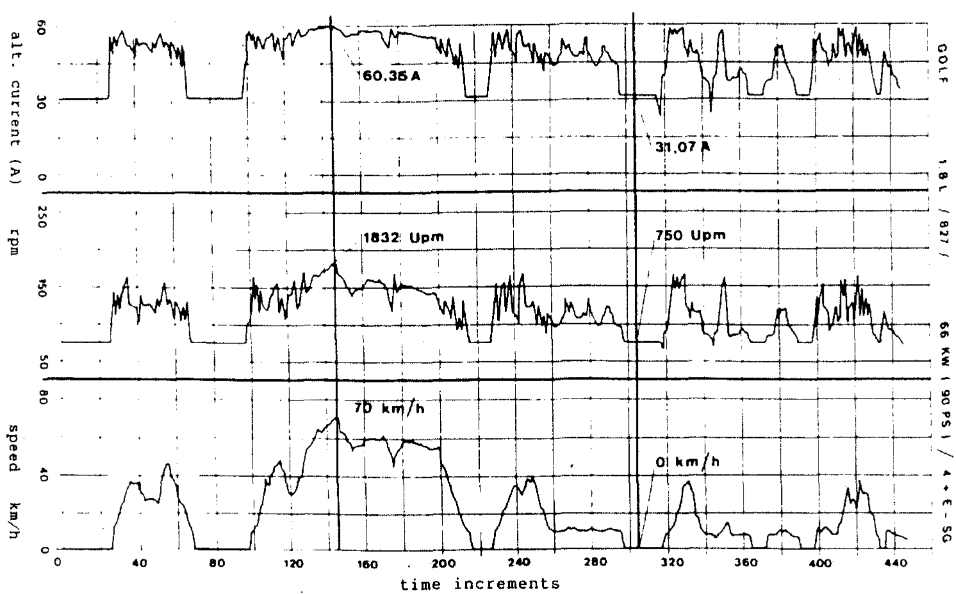

Fig. 5. Driving data during a city trip.

In order to obtain a reliable wiring system design, the considerations made here must be put into concrete terms. For this reason, a process for the calculation of the balanced current availability was developed at Volkswagen [4]. This analysis included: (i) the number and the nominal current of the consumers; (ii) consumer operating duration; (iii) the collective r.p.m. during one city trip. With this process, the alternator size and the capacity of the starter battery can be set down. In addition, the dimensioning of future wiring systems can be carried out through the simulation of new driving stretches and consumer combinations.

The high percentage of idling during city driving leads to the need for start–stop systems in which the engine is automatically switched off during idling periods in order to reduce the CO_2 output of the engine. The introduction of such systems leads to a further reduction of the available current.

The above considerations deal only with the critical case of the start of a city trip under poor weather conditions. An imbalanced current availability would lead to the battery becoming discharged within a relatively short time. This critical situation can be avoided, however, by increasing the duration of the major operating intervals. In this case, trips will also be included in the calculation during which the battery is completely charged. With an increase in these intervals, the battery is in greater demand as a high-performance energy buffer with a high capacity.

Quality requirements

In recent years, electronics has led to ever greater vehicle dependability and availability. This also becomes clear, among other things, by the longer maintenance intervals. As with all other parts of the automobile, the wiring system will also have to meet more stringent quality demands in the future. Here, an especially critical component is the battery, which must be developed in the direction of longer inoperative periods. In addition to the heavy discharging of the battery through future electrical consumers, the environmental conditions in which the battery must be operated will also play a major role. In the near future, batteries will continue to be installed in the engine compartment in many vehicles to allow electrical connections to power consumers to be kept short. This means that the batteries are exposed to high temperatures which, due to the largely closed-off engine compartments, already today have increased by up to 20 °C as compared with past generations of vehicles [5]. Therefore, a reduction in the water consumption, the application of hybrid technology, pocketized separations, and thermal shielding are required. Even if, eventually, such shielding precautions only represent a thermal low pass, studies at Volkswagen have shown that these measures considerably improve the situation during actual driving.

In the previous considerations, it was assumed that future energy-supply systems will possess the same structure as current wiring systems. This results primarily in an increased battery load. Therefore, design measures must be taken to optimize battery characteristics. Yet future power requirements cannot be fulfilled with battery improvements alone. Thus, it is also necessary to re-develop the wiring system itself. A few considerations on this topic are described briefly here.

New wiring system designs

The 12-V/24-V system

The increasing load on the 12-V wiring system has led to the suggestion that the consumers installed in the vehicle for heating purposes be separated from the remaining system and supplied separately with 24-V current (Fig. 6). While consumers designed for an operating voltage of 12 V would continue to be supplied by the 12-V system, 24-V current is planned for heating consumers. The advantage of this is that the heating consumers do not load the battery and, due to the high voltage, are operated with a high degree of efficiency. This process basically represents a simple positive disconnection, as certain consumers can only be operated with the engine running.

The 24-V system represents a further developmental stage (Fig. 7). This energy-supply system has already been installed in lorries and special vehicles. The advantages of this design lie mainly in the low currents for

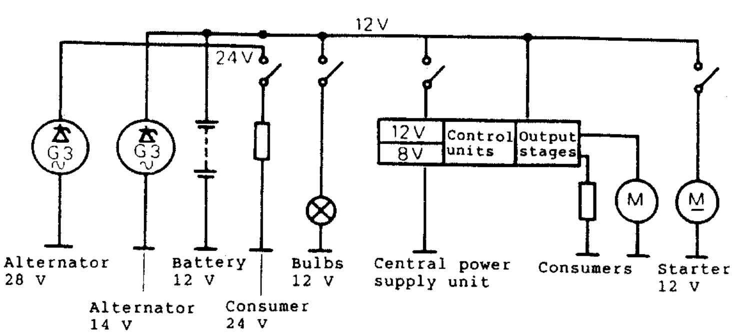

Fig. 6. 12-V/24-V wiring system.

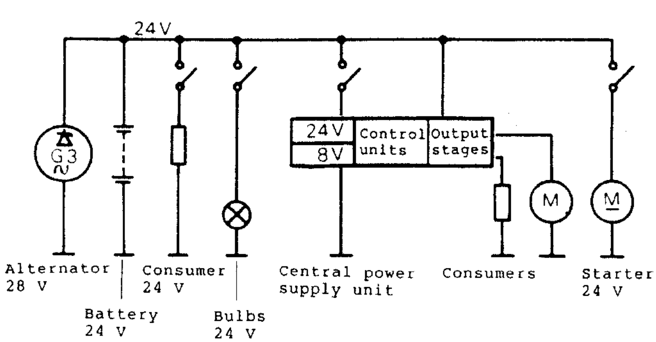

Fig. 7. 24-V wiring system.

powerful consumers (heating, starter) and the related reduced wire cross sections. It is disadvantageous, however, that nearly all electrical components for the passenger-car sector will have to be redeveloped. This also mainly applies to the battery, which must meet demands for reduced volume and weight with increased capacity and service life.

Energy management systems

Independent of the voltage range selected for the wiring system, it is definitely sensible to switch off consumers when the correct availability is negative. Pre-requisite to this is a central switch mechanism that disconnects individual consumers from the system according to established priorities (Fig. 8). The criteria for the disconnection must be set down in the switch mechanism programme. These criteria are, in the simplest case, prohibited combinations which, for example, prevent the switching on of seat heating during simultaneous operation of the rear-window heating. This type of control would ensure a balanced current availability taking a defined city trip route as a basis. The disadvantage here is that disconnections would take place independently of the respective driving habits and the state-of-charge of the battery. The introduction of an energy management system tied to a charge-level monitor would be considerably more comfortable (Fig. 9). This type of system would not implement disconnections until the charge level of the battery has dropped below a lower limit determined by the starting ability of the battery. In this case, the limiting value need not be permanently established, but can, for example, be 'learned' by including in the determination of the starting ability the current measured during previous starting and the outside temperature.

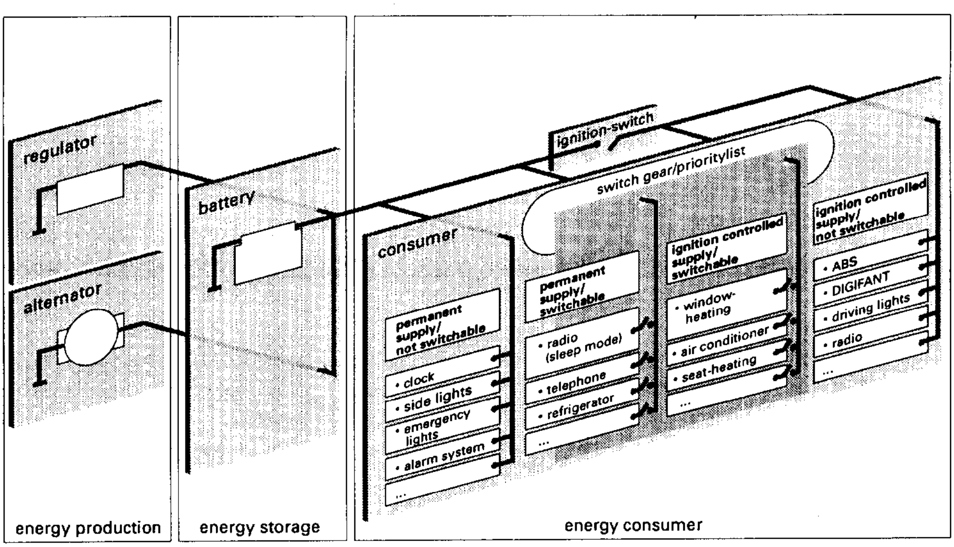

Fig. 8. Selective disconnection of individual consumers.

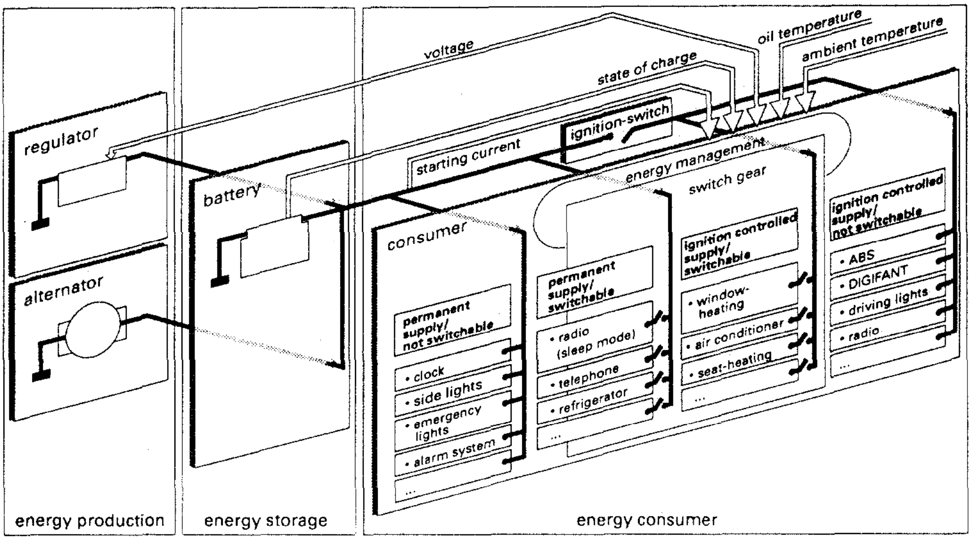

Fig. 9. Energy management.

In this way, the energy management system ensures that the vehicle can be started at all times, and it protects the battery from exhaustive discharging. Pre-requisite to the realization of the energy management system is, however, that a sensor for monitoring the battery charge level is available. This sensor must be developed and integrated in the battery.

Final considerations

Modern motor vehicles are increasingly equipped with electronic control units for the improvement of comfort and safety, and for reduced fuel consumption. The electronic control units themselves and the connected actuators require more and more electrical energy. In order that the customer can continue to use all these devices in the future without the dependable operation of his/her vehicle being endangered, the energy-supply system must be developed to meet these demands. This results in the following requirements.

(i) The power requirement of the current consumers must be minimized through the introduction of new technologies (24-V power system, CMOS), and their efficiency optimized. Electrical heaters must — as far as possible — be replaced with the use of engine heat (latent heat accumulators).

(ii) Electrical energy must also be efficiently used in the car, as fuel with a low efficiency is used for its production. Therefore, the keeping of power reserves on both the alternator and the battery side must be prevented by employing an energy management system for the intelligent distribution of electrical energy. In order to implement this type of management a yet-to-be-developed charge level sensor must be integrated in the battery.

(iii) Due to changing traffic conditions and driving habits, the battery will in future no longer be operated purely as a starting battery, but will also have to constantly supply switched-on consumers when the vehicle is stopped. This means that, with unchanging starting characteristics, future batteries must demonstrate increased cycle and temperature stability, and an increased capacity. In order to adapt the battery service life to the remaining wiring system components, measures must be taken to minimize water consumption.

Future progress in automobile design will also be determined by the advancement of the energy-supply system. It is only through the development of new electronic control units and their supply with electrical energy that new functions which improve the vehicle can be implemented. This also results in new requirements for both the wiring system and the battery.

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