42V Powernet Enabling Technologies: Overview

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Introduction

The arguments on "why" 42V should be the next generation vehicle supply have been made and played out elsewhere[1,2,3], to summarise these are primarily improved vehicle efficiency and an enabler of new features. The opportunity is also being used to "put right" some of the deficiencies in the 12V architecture, for example the voltage range on the power network is 21V to 50V operation, with load dump at 58V, this is significantly easier to accommodate than the 12V operating standards.

This paper aims to review the enabling technologies that provide the "how" to achieve the 42V Powernet electrical architecture in a vehicle. The transition from purely 14V to purely 42V electrical systems will not be a single "straight-swap" process and the intermediate mixed 14V/42V architecture is also be discussed.

There is impetus in the OEM vehicle market to begin early introduction of 42V systems into production vehicles. The reasons are many fold but mainly to prove the new technologies while gaining early in-vehicle development benefits from 42V systems (e.g. energy/weight savings).

The change from a 14V electrical architecture to a 42V system is probably the greatest single change to happen to the automotive industry, possibly since its inception. No other innovation has required such a complete change at the system level, the 6V to 12V change was not as significant as at the time only the starting, lighting and ignition (SLI) were the electrical loads on a vehicle. Today very few systems do not have electrical/electronic control and the trend is to increase the pervasiveness of electronics in the automobile.

Enabling Technologies

The following brief discussions are an examination of the technologies required to implement 42V architectures in a vehicle, the benefits of each, some of the technical challenges and some obstacles that may impede their implementation.

Engine Start

Engine starting is likely to remain via electromagnetic motor technology. Rewinding a standard 12V motor to 42V would not itself produce significant improvements other than reduced system losses, but by optimising the starter for faster cranking (higher initial torque) can reduce ignition from over 1s of today's 12V systems to under 0.5s. The benefits of rapid ignition starting are in reduced fuel consumption and consequent pollutant emissions reduction, this can be further enhanced by using the rapid-ignition to enable a "stop-start" driving regime for dense traffic situations.

Having a higher primary voltage will also aid the generation of reliable and rapid sparking for internal combustion engines and speed the heating of glow plugs in diesel engines. There is another alternative which is being pursued by several system suppliers; integrating the starter and alternator into a single electromagnetic machine (ISA, see below).

Electrical Energy Generation

Once the engine is running the electrical system is powered today by an electromagnetic alternator. Although essentially the concept will be retained, there are many possible alternatives to the alternator topology, each dependant on the overall system architecture. There is the possibility of retaining the existing 14V alternator along with a separate 42V device (i.e. dual alternators), this is a potential low cost entry into 42V system, but this would increase engine loading. Another alternative for the dual voltage vehicle is a dual wound alternator, having a 14V and 42V winding on a single stator. Even a single 42V output alternator could have a regulating control to provide a 14V and 42V output, however, loading factors could make control quite complex.

The other factor of the standard alternator topologies are the regulating components. More complex control schemes such as active synchronous rectification are in development for the next generation regulators. Other control schemes include the active suppression of load dump at the alternator.

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Integrating the starter and alternator into a single machine (ISA) provides significant system benefits at 42V. The ISA systems may be directly crankshaft mounted, which improved starting time and makes possible stop-start capability using the ISA machine itself in a semi-hybrid configuration. The crankshaft mounted configuration can also electronically perform the ignition damping function and hence remove the need for a crankshaft flywheel.

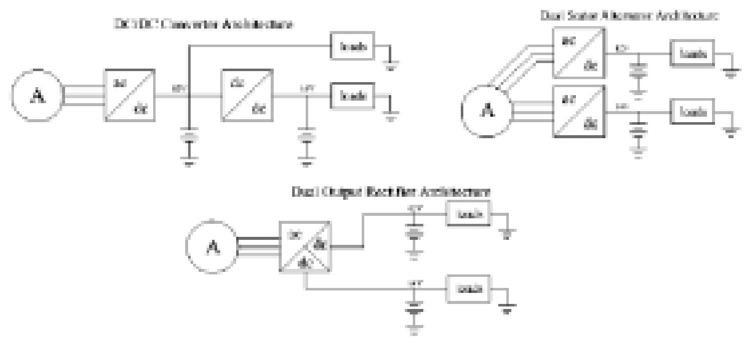

Figure 1: Potential 42V Powernet Alternator Architectures

Energy Storage

Battery technology for use in the automobile has hardly changed over the history of the industry. The standard lead-acid battery used today would probably be recognisable to Henry Ford. Although some studies have examined more exotic technologies, the general industry consensus is that lead-acid will continue to be the primary vehicle storage technology for the transition to 42V. The main improvements are likely to come from constructional changes such as absorptive glass mat (AGM) separators, spiral wound electrodes and power optimise battery (POB) configurations.

The move to a 36V storage capacity does have some potential benefits as the cost/weight ratio of energy storage is slightly lower for lead-acid at 36V (30 x 1.2V cells) than at 12V. The cost benefits will not be immediately available due to volume levels. The energy storage requirements are not yet well defined, as although the total electrical energy requirement in a vehicle will increase, few of the newer loads will be required off-key and some of the off-key loads can be made more efficient at 42V (36V). Another change will be the battery terminals, these will be polarised and non-user accessible.

During the transition phase, the dual voltage system may require dual battery configuration, only one may be primarily storage for off-key loads and the other dedicated to just the starting and ignition functions.

Power Distribution

Initially the expectation of weight loss in moving from 14V harnesses to 42V harnesses may be over exaggerated as many vehicle OEM's have been reducing wiring weight by a variety of other techniques. The move to bus structured signalling for example has reduced many wiring systems to their current minimum. Mechanical restrictions on minimum wire gauge in an automotive application also limits the weight savings possible. Even so best estimations for a given power demand suggest saving in harness weight of between 50% and 60% should be achievable in switching from a 14V to a 42V power architecture.

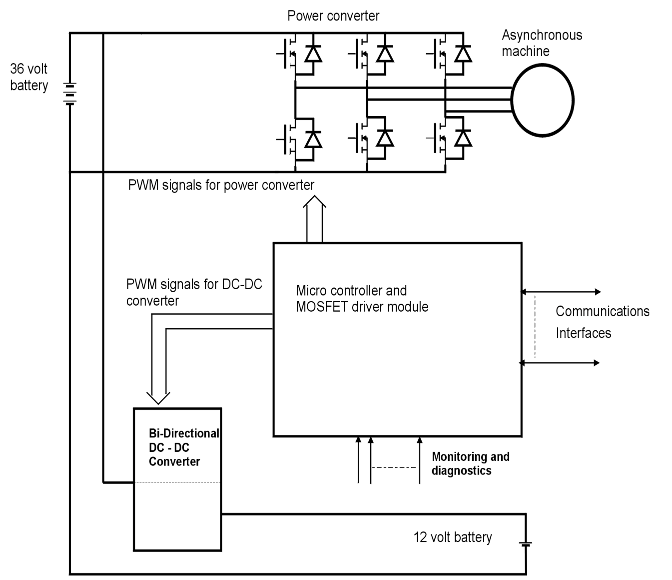

Figure 2: Integrated Starter-Alternator Architecture

It is unlikely that these sorts of savings will be directly observed as the power increase in electrical loads once 42V power is available and the interim transition utilising dual voltage distribution will make a direct comparison virtually impossible. Another reason for not realising the full potential in a wiring harness weight reduction is that energy savings can be obtained by using thicker wire than absolutely necessary for power distribution, hence a weight-electrical loss trade-off can be made.

One area of power distribution which is relatively new to vehicle applications is DC-DC conversion. During the transition phase there are a variety of architectures and configurations that will require a DC-DC converter between the voltage levels, either for utilising a single storage battery, or for top-up charging if dual batteries and a single rail generator is utilised. There will always be some DC-DC conversion (even today the 14V is down converted for electronic control systems to 5V or lower) but potentially half the vehicle electrical power (over 1kW) could be running through a DC-DC converter and in either up or down conversion modes (most existing studies are on bi-directional devices). Although some work has been conducted on these devices, not a great deal is publicly available, multi-phase conversion techniques in buck-boost interleaving topology is the MIT favoured scheme.

Whatever the eventual architecture, it is likely that some form of electrical energy management scheme will be implemented in the vehicle, similar in concept to engine management. The system will be optimised to ensure energy systems are neither overloaded or operating inefficiently and will probably have to interface with many of the sub-systems mentioned here.

Fuses

At 42V the potential for arcing and generating sparks is much greater than at 14V. Fuses in particular may cause a problem when live insertion/removal is necessary. Copper as a contact material has proved unsuitable as the metal is eroded by the spark and/or welded into its receptacle, more exotic precious metal contact blades are being examined and these appear to offer part of the solution. Protection of the fuse holder/receptacle from user is also requiring a redesign of the whole fuse assembly. Problems of contact arcing could also be problematic for 42V systems for the harness connectors and electro-mechanical relays.

The move to 42V Powernet could speed the introduction of “smart” fuses and semiconductor based protection technologies.

Jump Start

The main problem with jump start will be knowing what systems are being interconnected. The existing jump-start situation is relatively simple as all vehicles are 14V and the only potential problem is reverse connection (which is currently unprotected). At 42V the reverse protection is a more serious problem and polarised interconnecting leads are being developed for inter-42V vehicle jump starting. The main problems will occur with giving and/or receiving aid from a 42V to/from a 14V vehicle.

The primary solution so far proposed for this problem is known as the Smartpost. Smartpost is an intelligent jump start terminal that will sense the in-board battery(s) state-of-charge (SoC) and the SoC of the off-vehicle system connected at the post. The Smartpost then switches power between systems, ensuring the voltages are compatible (i.e. 14V-14V or 42V-42V) and that reverse polarity (if attempted) is protected.

Lighting

Although one of the simplest electrical systems on a vehicle, lighting has proved one of the most problematic for the change to 42V. Filament lamps are the dominant interior and exterior light source in vehicles today, filaments designed for 42V would be longer (hence require opto-mechanical redesign) and more fragile (i.e. shorter life) than their 14V counterparts. The lighting system is also a major energy consumer in a vehicle, requiring in the region of 350W in a typical medium saloon.

OEM’s would prefer to keep the 14V lighting systems, and this has been one of the reasons for the work on DC-DC conversion schemes. It has been recently shown[5] that many of the perceived limitations can overcome by the use of pulsed control of the lamps directly from the 42V rail to produce equal light output and lifetime to a standard 14V system.

Other lighting technologies such as high intensity discharge (HID) and neon will benefit most from a switch to 42V as these are easier to operate at higher voltage. Light emitting diode (LED) technologies are not predicted to have significant problems operating from a 42V Powernet.

Small Motors

As with lighting, small motors present a potential problem with the move to 42V. Rewinding for 42V will increase their cost and may increase size. At 42V arcing and brush wear becomes a significant problem for many of the permanent magnet motor types used. A similar approach as used for the filament lighting may be a solution and this is currently under investigation. One particular problem in small motors is stall current when this is used to determine end-of-motion, with a 42V supply these currents are much higher than with 14V, hence additional detectors or faster sensing is required.

Semiconductors

The semiconductors required for use in a 42V system are generally already available, many in use in telecommunications (48V nominal). The load dump requirements at 42V are tighter than the existing 14V system and in many cases the same power semiconductors can be utilised. Devices for use at 42V are readily available and several power semiconductor companies are developing specific products for 42V applications.

Other Systems

Systems which use large motors, such as electrical power assisted steering (EPAS), should benefit from a change to 42V, the available power from 14V is currently preventing more EPAS being adopted in many medium sized vehicles. This will bring benefits in reducing both on-engine loading and potential weight reduction, hence improved vehicle economy and promises to make assembly easier (fewer hydraulic systems between engine and ancillaries).

Another area that should see major benefits from the move to 42V is heating systems, these can either be made faster by operating at a higher current level (important for catalytic converter heaters for example) or made to operate with thinner wire (e.g. rear window heater). Heating systems is a particular are where some early 42V systems are being implemented on otherwise all 14V vehicles.

New Systems

Once more power is available, more electrical systems will probably be introduced to the vehicle, two which are waiting in the wings are electronic power valve systems (EPVS) and drive-by-wire. EPVS is a system that can require several kW of energy to operate, however, the higher energy requirement occurs at high engine speed, hence does not impact storage requirement only the power generation side. It is probable that EPVS can in fact not be realised until 42V is available.

Drive-by-wire can mean many things, but essentially here it is considered as the general trend towards replacing mechanical and hydraulic linkage between driver and vehicle with electrical systems. The replacement of many of the systems is currently limited by safety legislation, but true electric power steering (EPS) for example, without the mechanical torsion beam linkage (assistance) is not possible even on small vehicles with the current 14V architecture.

Standardisation

A proposed standard for the 42V Powernet electrical voltages has recently been submitted to ISO. Sican is working as part of the Bordnetz group on most standardisation issues.

Summary

Many of the technologies and systems to enable the introduction of 42V Powernet into production vehicles are well understood and in development. The main hurdle is the acceptance by the OEM and vehicle buyer of a system change which in itself does not provide any direct benefit, but is an enabler of future technologies and can offer improved economy benefits in today's vehicle technologies.

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