X-by-Wire, New Technologies for 42V Bus
Automobile of the Future

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Submitted in Partial Fulfillment
Of the requirements for
Graduation with Honors from the
South Carolina Honors College

April, 2002

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Thesis Summary

The automobile is an integral part of modern society. With each passing year come new advancements to this marvel of mankind’s ingenuity. For the past fifty years, car’s electrical systems have run on a 14-volt bus enabling 12-volt applications. In the past twenty years power requirements of automobiles have more than doubled. Today’s cars with all of the added amenities and advance operational systems have nearly reached the limit of the 14-volt system. The industry has agreed that the next step in development is to triple the voltage used in automobiles.

Many developments are being made toward implementing the new 42-volt bus that enables 36-volt applications. A select number of companies already have 42-volt systems integrated into production vehicles. There are many difficulties facing designers concerning the adaptation of automotive systems to 42-volts. With hundreds of electrical applications in the modern automobile, configuring an entirely new platform on which these applications will run is very challenging. As the world comes near to a new automotive standard for electricity, researchers and car manufactures are busy developing applications to utilize the new power and improve vehicle performance.

The main area of development is one commonly referred to as X-by-Wire. This is a generic term used when bulky and inaccurate mechanical systems are replaced with sophisticated electrical components. Implementation of X-by-Wire usually results in more efficient processes and increased performance. Some of the major areas being considered for X-by-Wire development are steering, braking, suspension, and engine management.
A major issue driving this development is the need for improved fuel efficiency. With an ever-increasing awareness of the limited nature of natural fuels, efforts are being taken to reduce consumption. The transition to a 42-volt system and the corresponding application advancements promise to reduce the amount of fuel consumed by automobiles. By increasing the power available in cars, additional safety components can be added. These developments will ultimately result in improved performance, giving cars better acceleration and handling; added comfort, providing superior climate control; and greater convenience, with everything from on-board traffic analysis to the latest video games for kids.

Abstract

The automotive industry needs more electrical power to continue to incorporate the latest technologies in their designs. The current 14-volt bus has become insufficient. The solution is to integrate a 42-volt bus into future automobiles, thus providing the necessary power. With additional power supply on the horizon, many new systems, such as X-by-Wire, are being developed to utilize the potential of the 42-volts. These upcoming changes will bring about improvements in fuel efficiency, power, safety, comfort, and convenience.

Introduction

New technologies to aid in automotive efficiency and convenience are emerging onto markets; however, they cannot be utilized due to electrical power constraints. The current 14-volt bus employed by modern automobiles is insufficient
to meet future demands. Car manufactures agree that the solution is to triple the voltage and implement a new 42-volt bus. The anticipation of this additional power availability is opening the floodgates of research into electronically controlled automotive systems, also know as X-by-Wire. The effects of these advancements will be seen in areas ranging from comfort and convince to efficiency and power. In this paper, changes to current systems and new technologies brought about by the 42-volt bus will be investigated.

**Why 42 Volts?**

In the past 20 years, the electrical demand of automobiles has more than doubled [19]. Figure 1 shows the trend of power usage in passenger vehicles over the past 80 years and gives a projection over the next 20. The present 14-volt system is being stretched to meet the current electrical needs. The greater the demand placed on an overloaded system, the more inefficient the system becomes, thus, reducing fuel efficiency. With a 42-volt system the operating efficiencies are much higher.

It is obvious that automobiles need a greater amount of electrical power then they currently posses, but why 42 volts? The higher the voltage used, the more
efficient it will become because higher voltage systems experience less power loss in transmission [3]. So why stop at 42 volts? It is accepted that D.C. electricity as high as 60 volts is safe and does not require special materials. If the peak voltage in a system were to exceed 60 volts, then advanced materials and safety precautions would have to be implemented thus driving up the system costs. A 42-volt system would meet government regulations for safety and provide adequate power to run all current electrical applications as well as those emerging in the foreseeable future [6].

Transitioning Between Systems

The current system is comprised of a 14-volt bus, or nominal voltage, and a 12-volt battery used to power 12-volt applications (hence the common nomenclature “12-volts”). This 14-volt system has been in use since the mid-1950’s. Automobiles prior to this time used a 6-volt system. Engines featuring higher compression then their predecessors needed more powerful starters. The switch from a 6-volt to a 14-volt system was completed within a few short years [3]. In the 1950’s there were few electrical applications in automobiles so changing from one platform to another was relatively simple. Current automobiles operate at near full electrical capacity running everything from onboard diagnostic computers to powerful 12-speaker sound systems. In 1998 the average vehicle had 35 microcomputers and by 2010 60 microcomputers are expected. For more electrical applications see Appendix A. The transition from a 14 to a 42-volt bus will be much more complicated then its previous equivalent. The transition will happen in a series of awkward stages as many vehicles
will use a combination of 14 and 42-volt systems until the producers of electrical components adapt to the new standard.

The time for the transition to be completed is hard to determine. With each passing year estimated production dates get pushed back a little further. Toyota is currently the only company offering a 42-volt bus. The Toyota Crown Royal Saloon comes with a 42-volt option [18]. Renault plans to produce a dual-voltage vehicle in 2004 (one using both 14 and 42-volt sources). Their goal for a complete and independent 42-volt system is as early as 2007 [3]. The government plans to regulate a transition within the next five years; however, the date has already changed many times. The changeover will first begin in Europe and Japan where gas prices and emissions standards push the global market. BMW, Mercedes, and Fiat all have plans to move to 42-volt systems in the 2002/2003 model year [6].

**X-by-Wire**

While it is true that increasing the operating voltage of the current automobile will improve efficiency and increase gas mileage, the true potential of this endeavor can only be seen by exploring the new electrical applications the 42-volt bus will allow. Automobiles, at their onset, were nearly entirely mechanical. Throughout a century of development, more and more systems have come to be controlled electronically. Electrical components provide increased control and are not as prone to wear as mechanical devices. By eliminating frictional losses associated with mechanical members, electronic controls offer higher efficiencies.
X-by-Wire is the generic term used when clunky and inaccurate mechanical systems are replaced with precise electronic sensors and actuators. Many of the advancements to come as a result of the 42-volt bus can be lumped into the category of X-by-Wire. This X-by-Wire trend has been evident in the automotive industry for years. The trend can be seen in the implementation of fuel injectors to replace their bulky counterpart, the carburetor, and in the development of electronically controlled brakes known as ABS. X-by-Wire is not a new program to implement, but a term capturing the existing trend of development and pointing in the direction of future advancements.

Many are hesitant to move to X-by-Wire for reliability and safety concerns. Conventional mechanical systems have stood the test of time and have proven to be reliable. More than a decade ago, the United States Air Force went through a similar struggle in the changeover from mechanical and hydraulic linkages to electrical connections in aircraft. The now indispensable fly-by-wire endured much scrutiny at its conception. An electrical failure could be catastrophic to any X-by-Wire system. In military applications, such a failure would be totally unacceptable. Military craft are required to function in some of the most extreme conditions in the world with unacceptable consequences of failure. Redundant electrical systems were developed and have been implemented in both military and commercial aircraft over the past decade. Fly-by-wire has allowed improvements to the military that would have otherwise been impossible. New standards being met by military aircraft could only be achieved using X-by-Wire. The latest air force development, the F-22 Raptor, is fully fly-by-wire, enabling it to perform maneuvers once thought impossible. X-by
wire systems are now being incorporated into military land units as well. The new  
Grizzly Tank, the army’s high-tech ground-assault vehicle, utilizes X-by-Wire [2]. The military has proven that X-by-Wire can be both reliable and highly effective.

42-volt Applications

Starter-generator

The most anticipated and fully developed 42-volt application is a combination  
of a starter and an alternator referred to as a starter-generator. Within the current 14-volt architecture, the starter must generate substantially more power than the  
alternator. The alternator must only keep up with the electrical consumption of the automobile, while the starter has to provide substantial force to begin the internal combustion process. With power requirements for cars exceeding 5kW, and with cranking torques becoming lower thanks to engine friction reduction, it becomes  
practical to combine the starter and the alternator into one single unit [8].

Incorporating these two functions into one unit has many advantages. One of  
the greatest advantages of the starter-generator is that it allows engine cut off during coast down. Visteon Corporation has developed a starter-generator featuring a restart time of 300ms [10] (seen in Figure 2). This means
that when a vehicle is slowing down or stopped, it becomes possible for the engine to stop running to save fuel. When the driver wants to accelerate again the engine is restarted with such a short delay that the lag in nearly unperceivable. An idle-stop system is included in the 42-volt package currently being offered on the Toyota Crown Royal Saloon [18].

Another area of great potential for the starter-generator is its brake regeneration capability. Some energy produced by the engine is currently dissipated as heat in the braking process. Effectively utilizing regenerative braking would cause gas mileage from city driving to approach gas mileage obtained while driving on an interstate. Starter-generators can offer this regenerative potential when they are placed in-line with the crankshaft. This “in-line” placement of the starter-generator is the most popular and the most promising. The generator provides power to the battery by taking energy directly from the crankshaft. When the car is braking, the engine stops, but the generator continues to remove energy from the crankshaft, thus slowing the wheels and capturing some of the power that would have been expended as heat in the brake pads.

Regenerative braking is not the only reason to keep the starter-generator in-line with the crankshaft. During high torque demands, the electric motor portion of the unit can add power to the system resulting in improved acceleration and towing capabilities. The system also provides easier and quieter vehicle start. Visteon’s starter-generator increases fuel efficiency by 6 to 12% and reduces emissions by 10 to 15% [10].
Belt-Driven Devices

Current air conditioners, oil pumps, water pumps, and cooling fans are all driven by belts connected to the engine. Using a starter-generator the engine will cut off at various times during operation; however, it will be imperative that these belt-driven devices do not. All of these devices will become electronically powered rather than mechanically powered. Air conditioners will use electric motors to drive their compressors. The pumps and fans will also be driven electronically.

Electric Exhaust Reducers

Catalytic converters reduce carbon monoxide, hydrocarbons, and nitrogen oxides, the three most dangerous pollutants produced by the internal combustion engine. This is done by passing the exhaust gases across a combination of reducing and oxidizing catalysts at high temperatures. In this process, the harmful chemicals are broken down or changed into safe byproducts. Catalytic converters perform their function well, but only at high temperatures. The first several minutes that a car is running, dangerous fumes are being released until the converter comes up to temperature. Under the current 14-volt system an electric heater would take nearly the same amount of time to heat the converter as the heat exchange from the engine; however, with 42-volts available, an electric heater could be incorporated into the system and the converter could be brought up to a suitable temperature in a short period of time.

With higher voltages available, plasma exhaust processing becomes a possibility. In this process, exhaust gases are passed through a high voltage field,
essentially eliminating nitrogen oxide components. This process requires a large amount of energy and is still being modified to be more economical [19].

**Throttle-by-Wire**

Conventional throttle systems consist of a cable running from the gas pedal through the firewall and into the throttle body. This cable slides within a housing as it winds its way around various components. Such a system is relatively bulky and prone to wear. The system needs periodic service for oiling and adjustments. Some automotive manufacturers are beginning to implement a new means of throttle control known as Throttle-by-Wire.

Throttle-by-Wire is currently being implemented in the C5 Corvette, the Acura NSX, and the Toyota Tundra [2]. Throttle-by-Wire consists of a sensor providing pedal position. The data acquired by the sensor is sent to the Engine Control Module (ECM) that receives information from several other components and determines the parameters to change. The ECM coordinates components such as ABS, gear selection, fuel and air intake, and traction control [2]. This embedded intelligence results in increased fuel efficiency, reduced emissions, and improved performance. With Throttle-by-Wire, information is transmitted electronically rather than mechanically so there are no frictional losses. With fewer moving parts the system is lighter, more accurate, and nearly maintenance free.
Brake-by-Wire

Power braking systems are bulky and complex. They rely on mechanical linkages, airtight vacuum seals, and hydraulics. When the brake pedal is pressed, the force is amplified using a lever. From there a vacuum generated from the engine is used to assist the brake pedal motion. That motion is transferred through hydraulic fluid in all directions until it reaches the braking unit on each wheel. This complex configuration can be simplified and improved using Brake-by-Wire.

Two levels of Brake-by-Wire exist. The first is called Electric Hydraulic Braking (EHB). In EHB electric pumps and valves are used to power and control the hydraulic elements. This reduces the power draw on the engine and eliminates some of the large cumbersome interfaces. In EHB the driver inputs are interpreted electronically allowing computer-controlled coordination between the braking and other systems. Another advantage of EHB is the possibility of mechanical backup. Since hydraulics are ultimately responsible for stopping the vehicle, they can be configured to apply a braking force in the case of electrical failure [7].

The second level of Brake-by-Wire is called Electric Mechanical Braking (EMB). EMB consists of sensors on the brake pedal, a control unit, and electromechanical actuators at each wheel. This system holds the greatest potential for control and variability. It would also be the easiest system to manufacture and package and thus the cheapest. Assembly time would be a fraction of the current design. Regenerative braking would be easier to develop and implement. Maintenance would be reduced due to the elimination of brake fluid and mechanical linkages. Using EMB, a mechanical backup cannot be realized. The electrical
components must be designed fail safe. Electrical redundant methods are being developed. One promising approach to fail safe electronics is known as “Time-Triggered Protocol (TTP)” [7]. This fail-safe approach is being developed for use with Brake-by-Wire and Steer-by-Wire systems.

Steer-by-Wire

Steering systems have undergone substantial changes from their onset. They began as a direct link between the steering column and the front two wheels. With automobiles increasing in weight the forces required to turn the wheels (especially while stopped) became unreasonable. The next step was to produce a favorable gearing ratio. One such method used to produce the necessary mechanical advantage is the rack and pinion displayed in Figure 3. Having maximized the reasonable gearing ratio, hydraulic assist was added—know as power steering. This is the current system on most automobiles; however, it is very complicated and requires excessive energy. A hydraulic pump is driven by belts from the engine. This pressurized fluid is used to assist the steering shaft in the direction it is turned. One of the main problems with hydraulic assist is one of available timing. The pump must generate enough pressure to turn the vehicle while stopped (the hardest time to turn) when the engine is running at idle rpm’s. When the engine speed rises and the vehicle speed is
increased, the pumping power being drawn from the engine is excessive. Hydraulic systems also draw continuous power even when power steering is not needed. The next logical advancement would be what is called electro-hydraulic steering. This is where the hydraulic pump is driven by an electric motor allowing the pump to provide only the needed pressure to aid in turning. Electro-hydraulic steering substantially reduces power consumption; however, due to the nature of hydraulics, pressure must be maintained so the power usage is continual.

A new advancement currently finding its way into markets is referred to as electrical assist steering. In this system the hydraulics are replaced by electronically controlled sensors and actuators. The sensors determine which way the wheel is turning and cause the actuators to provide additional force in that direction to aid the mechanical linkage. With this configuration energy is not wasted as with hydraulics. Energy is only used when the wheels are turned [13]. The mechanical linkage provides continual control in the case that electrical energy is lost. Substantial frictional losses and time constraints still exist from the mechanical connection.

Removing the mechanical linkage between the steering wheel and the tires would simplify the design, increase efficiency, enhance performance, and improve overall safety. This completely electrical system is called Steer-by-Wire. A Steer-by-Wire system would consist of a position sensor on the steering wheel, a motor providing forced feedback to the driver, actuators on the front two wheels, and a control unit to coordinate the process. These four components would mark a substantial reduction in the number of parts as well as in the size and weight of the overall system. The process is very efficient because power is only consumed when
the wheels are turned. The control unit receives data from other systems so when the tires are turned, only the necessary force is applied based on the instantaneous driving conditions. Performance is enhanced because the steering ratio (how far the steering wheel turns relative to how far the tires turn) is fully variable based on speed, traction control, and other pertinent variables. Safety is improved in the case of an accident. The driver is the most at risk in an accident because the steering wheel is forced into the driver by the steering column. By removing the steering column, many of the injuries and fatalities experienced in automotive collisions could be eliminated.

Steer-by-Wire is currently being used by large construction equipment, forklifts, and military ground units. Delphi has announced a new innovation scheduled to reach consumers in 2003 called Quadrasteer. Quadrasteer is a four wheel steering system utilizing Steer-by-Wire on the rear two wheels. This four-wheel steering system is designed to aid large trucks and SUVs while maneuvering in small spaces as well as increase stability at highway speeds. While many four-wheel steering systems have been used, Quadrasteer is the first to implement Steer-by-Wire. Steer-by-Wire has many advantages in the Quadrasteer system. By being computer controlled, the rear tires can change the way they turn based on driving parameters. When the vehicle is moving slowly, the rear tires turn in the opposite direction from the front tires to aid in maneuvering; at high speeds the rear tires turn in the same direction as the front tires to reduce yaw and improve stability [14]. If the Steer-by-Wire on the rear wheels were to fail, the front steering system would allow the driver to maintain control. The advantages of Steer-by-Wire are clear; however, reliability concerns slow its implementation into front steering systems.
Active Suspension

Automotive suspension is a compromise between comfort and control. Suspension systems are comprised of springs and dampers that store and release energy. Spring rates and damping coefficients are adjusted to set the balance between these two opposing criteria. Using conventional means, this compromise is set once and for all in the developmental stage. Whether it is a suspension system for a Cadillac limousine or a Ferrari sports car, some balance between comfort and control is chosen. Active suspension is the name given to an approach that allows this compromise to vary based on driving conditions.

The first level of advanced suspension is semi-active suspension. In this system one or more parameters of the suspension are automatically varied based on sensor inputs. The adjustments capable of on-the-fly manipulation are the ride height of the vehicle, the stiffness of the damper, and the spring rate. The alterations are accomplished by changing either the pressure in the components or some internal geometry. Fast acting valves are used to change orifice size and control the movement of fluid. The dampers are be adjusted by altering the size of the hole between the two compartments. Spring rates change based on the available volume the fluid can fill. Overall ride height is controlled by the pressure in the chambers of the shock absorber unit. Using pumps, reservoirs, and valves the parameters of the suspension can be varied [5].

Fully active suspension is quite simple in concept but challenging in design. It consists of four actuators, one at each wheel, and sensors and software to control
them. Fully active suspension detects bumps and compensates for them before the passenger compartment responds. It is capable of eliminating roll, pitch, and yaw. Cars with full-active suspension can “lean” into turns to improve handling [5]. Fully active suspension is a goal of suspension designers; however, the power requirements and cost considerations make it unpractical at the present.

Combinations between semi and fully active suspension also exist. These are known as series active and parallel active. These systems incorporate springs in either series or parallel, as their names indicate, with actuators. Series active systems reduce the necessary bandwidth from that of fully active, while parallel active ones reduces the load that the actuators must carry [12]. Diagrams explaining the configuration for the four types of suspension mentioned are shown in Figure 4.
The price of improved comfort and control is seen in the increased weight, power consumption, and cost of active suspension systems. Sensors are needed to monitor functions such as, road modulations, steering, braking, speed, and vehicle position and acceleration in three dimensions. Complex logic is required to account for all possible driving conditions. Fully active suspensions need actuators capable of large displacements (several inches) in microsecond time intervals [11] under loads of
several thousand pounds. The tires are capable of absorbing frequencies above 20-40 Hz, but the actuators must eliminate the rest [12].

Semi-active suspension is becoming a reality in production while fully active systems remain distant. Volvo has included electronic controlled dampers designed by Ohlins Racing and Tenneco Automotive in their Four-C system. This Continuously Controlled Chassis Concept is one of the most advanced active suspensions systems available. Citroen has developed a parallel active system that is being used on the Infiniti Q45 (Model G50 series). Pressure in the shock absorber can range from 0 to 1400 psi and are aided by spring supports [5]. 42-volt electronic architecture will aid in the implementation of active suspension system; however, this is an area still open to much development.

**Variable Valve Timing**

Internal combustion engines are powered by the rapid expansion of exploding gases. This energy is harnessed and transformed into useful motion by the downward thrust of a piston. Gas and air mixtures are brought into the combustion chamber, pressurized, and waste products are exhausted with the use of engine valves. Engine valves are traditionally controlled with a set of cams being driven on a shaft known as the camshaft. Figure 5 shows the

![Figure 5: Valve/Camshaft Configuration [17]](image)
basic configuration. The camshaft is belt driven using the power from the engine via the crankshaft. The cams interact with the valves causing the necessary movement. Cams exhibit a specific profile; therefore, once the cams are chosen and designed the valve timing is fixed. The timing is a compromise between fuel efficiency and performance [1], allowing the engine to function at a wide range of rpm’s. The result is a functional yet inefficient system. Altering the valve timing results in a new balance between the desired criteria. Variability in valve timing would yield improved fuel efficiency, increased power, and reduced emissions over conventional designs.

One method being employed to alter valve timing is to physically change the cam profile in mid operation. BMW has produced a system known as Valvetronic where a stepper motor turns an eccentric shaft altering the displacement and timing of the valve actuation. The Valvetronic configuration can be seen in Figure 6. Honda’s VTEC engine incorporates three separate cams. Each cam is designed for optimal operation at a specific engine speed [1]. The mechanics of shifting between three cams at every change of engine speed is very complex and inherently prone to failure. Ferrari’s approach has many advantages. Ferrari
has integrated into their engines, cam lobes with continually varying profiles. As the engine speed increases, the entire camshaft is moved linearly to provide a unique profile at each operating speed [16]. This variability improves engine operation; however, fully variable valve timing would allow additional advancements.

Another method of valve timing control is to electronically adjust the rotation of the cam. The camshaft can be powered with an electric motor giving some variability of the valve timing. Each cam may be powered independently. This allows slight alterations in valve timing as well as the possibility of reducing the number of acting cylinders. A car with eight cylinders can use the power of all the cylinders during acceleration and then turn off selected cylinders by closing their valves during cruising conditions.

The ultimate in variability of valve timing comes from the use of electromechanical actuators controlling the valves. In this case, the timing is only limited by the actuators speed and accuracy. This approach to valve control is referred to as the “camless engine.” Much research is being done to develop actuators to drive the valves with sufficient speed, force and control. The most common approach involves the use of solenoids. Sturman Industries was the first to successfully incorporate solenoids into a fully functioning camless engine. Their diesel truck ran in the Pikes Peak race (a test of endurance for any vehicle) with success [9]. Diesel engines have been the first to go to camless because they require slower valve actuation times. Solenoids are fast and provide reasonable power but they lack the control that would allow idealization of the timing. Solenoids are binary units, they are on or off; it is therefore hard to customize a valve profile using these
devices. FEV has developed actuators that using electromagnets to hold the valve in the end position. They are achieving full displacement in 3 ms [4].

Another approach to camless engine actuation is through the use of hydraulics. At the University of South Carolina researchers have developed a piezoelectric controlled hydraulic actuator. This design incorporates the strength of hydraulics with the response time of a piezoelectric crystal [1]. This allows fast actuation while being able to quickly change the flow characteristics for soft valve seating and full variability in between. This increased control allows alterations to be made at any stage of valve actuation to account for any number of changing parameters and inputs. Increases in actuator control, power, and speed will lead to camless engines with notable improvements to vehicle functionality. 42-volt availability makes the camless engine possible. The increased electrical power enables the support needed for advanced actuators.

Electrical Accessories

With the implementation of 42-volt systems into automobiles, the floodgates are opened on an already abundant reservoir of electrical accessories. Although many of these applications may seem trivial, in a society driven by comfort and convenience, these novelty items will be as large a driving force in the transition as fuel efficiency and emission reduction. In an SAE webcast conducted in March 2002, a pole was taken of the reasons America would move to a 42-volt bus and the overwhelming answer was for comfort and convenience [20].
Comfort is one area that will improve with additional power availability. Electrically heated seats and steering wheels will be more common. Supplemental heaters will be available in diesel vehicles where the engines do not reach temperatures necessary to fully heat passenger compartments in cold weather. Advanced climate controlled systems will allow individual passengers to all travel at their ideal temperature.

Programmed profiles will be stored for various drivers and the appropriate adjustments will be made automatically. With the push of a button the seat, mirrors, and steering wheel will be adjusted from a 6 foot 2 inch husband’s settings to those of his 5 foot 2 inch wife. Even driving profiles from pedal and steering wheel responsiveness to suspension stiffness will be stored and altered.

High-end sound systems reaching power requirements of 5 to 10 kW [19] will be supported by additional power availability. Televisions and game systems to entertain passengers and business machines such as laptops and fax machines will all be aided by the increased electrical power.

Navigational systems will have the potential to be further developed and modified. Voice commands telling the driver where to turn when traveling to an unfamiliar destination will be incorporated. Signals will be received communicating the road conditions ahead and warning of accidents or other potential slow downs. These systems will be able to plot alternate routes and keep traffic flowing more smoothly.

As more of the automotive components become electronically controlled, increasingly powerful computers become a necessity to coordinate and guide these
devices simultaneously. The electronic steering may vary based on the status of the fully active suspension and compensations will be made. When a collision is perceived as eminent, an extendable bumper may be activated to absorb some of the impact from the collision. Computers will be constantly monitoring and adjusting the thousands of different parameters all working together within the vehicle.

42-volt Obstacles (Research Opportunities)

The move from 14 to 42-volt applications is not as simple as changing a battery and the number of coils in electronics. New components need to be designed rather than modifying existing products. The electronic architecture of vehicles must be redesigned and reestablished. Some components, such as headlights and logic devices do not work well at the higher voltage. Filaments used in headlights must be thinner in a 42-volt system; they are therefore more prone to failure. The question remains whether two separate power sources will be used or if a dc-dc converter will be integrated. Toyota’s current design utilized dc-dc conversion. A third option being investigated is an alternator that can output both voltages simultaneously [18].

Electrical systems must be developed to address physical phenomena encountered with a 42-volt bus [18]. At 42-volts arcing and electrochemical corrosion become areas of concern. 14-volt arcs are very unstable so they brake down as soon as they form, but 42-volt arcs are only unstable if a sizable gap exists between the electrodes. The arc levels jump 50 to 100 times from 14 to 42-volts [15]. Electrochemical corrosion is also speed up with the increased voltage; however, this jump is proportional to the voltage increase.
Another necessary source of development is in electromechanical actuators to enable the numerous X-by-Wire applications. A 42-volt vehicle will need actuators that are faster, stronger, more efficient, and more accurate than currently available products. The most challenging use for actuators will be in fully active suspension. Such a system must respond extremely quickly, be very strong, use minimal energy, and all without the passengers feeling a bump. These actuators will need millisecond response time with a displacement of several inches.

**Conclusion**

New technologies are being developed everyday. X-by-Wire is the clear trend of automotive development. The current 14-volt bus is insufficient to run the applications emerging on the market. Transitioning to 42-volts will bring about improved fuel efficiency, increased power, higher levels of safety, greater comfort, and countless new connivances. Standards for the 42-volt system need to be quickly defined so that research efforts can be guided in unison. Much work has been done and much remains to do. The question of “When?” is difficult to answer, but the direction for the automotive industry is clear.
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References


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