

Powerline Communication in Drive-by-Wire Vehicles with Redundant Data Networks using DC-BUS Components

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I – The Requirements on Fully Drive-by-Wire Vehicles

Fully drive-by-wire automobiles are unlike today's vehicles. The principle of being fully drive-by-wire calls for the exclusive, electrical transmission of all driver control functions using digital signals to the likewise electrically operated actuators. In particular, this involves the steering movements and the brakes, in addition to the engine and transmission controls. The benefits are obvious: Eliminating mechanical steering and the costly, involved configuring of hydraulic brake systems alone will open up heretofore unheard of freedom in using the available design space – not to mention easier assembly and new opportunities in the realm of active vehicle safety.

The material presented here is based on the lessons learned and solutions derived from DaimlerChrysler's current Project SPARC (www.sparc-eu.net).

Steering and braking are of course safety-critical vehicle functions. Absolute redundancy is a prerequisite for electrically operating the steering and brakes and electrically conveying the

related commands: redundancy in supplying the actuators with sufficient electrical energy and redundancy in transmitting the information that controls them. It goes without saying that there must be adequate electrical power available regardless of what state the vehicle is in. This in turn requires reliable, diagnosable electrical-energy stores (smart batteries).

Redundancy involves a relatively minor expense when it comes to delivering the power. This job can easily be accomplished by using a dual configuration of smart batteries together with two power diodes, which divide the power supply into two independent energy-supplying networks. | **Fig. 1)**

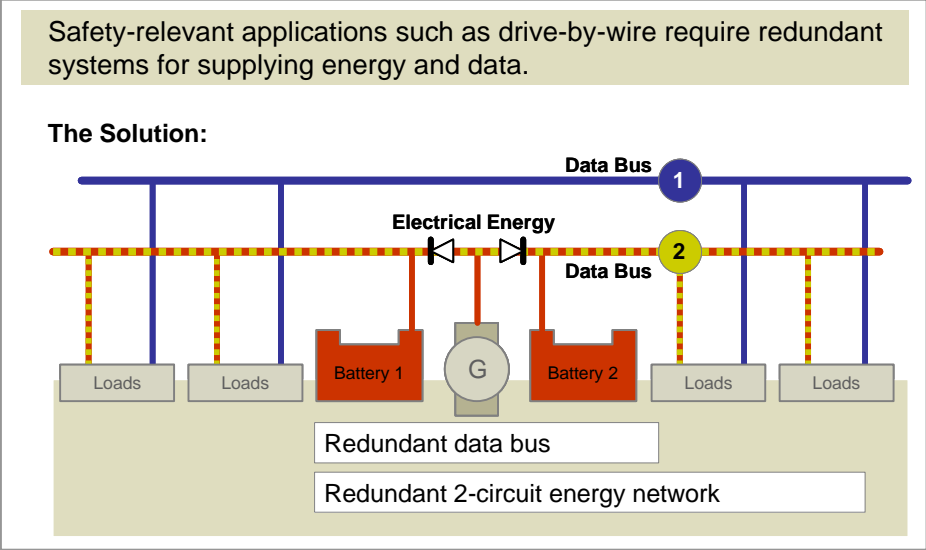


Fig. 1)

Here the steering is connected to two separate electric motors, which are powered by one of the two autonomous energy stores. Only one of the motors operates during the steering process while the second is in stand-by mode. This second motor takes over instantly if there is any outage of the first motor.

Redundant data communication, on the other hand, is not so easy a task. The design space in today's vehicles is extremely limited and the wiring harnesses are already as complex and expensive that any additional datalines would be a solution that is neither sensible nor desirable.

And so, the thing that lends itself to providing the needed redundancy are the power lines, which means we can utilize the existing power-supplying cables and wires as a data highway. | **Fig. 1)**

II – Principles of Powerline Communication or PLC

There is nothing new about the idea of using the powerlines for transmitting both energy and data. The first attempts at this kind of powerline communication had already been made 25 years ago, but failed when unable to overcome a number of fundamental problems. It is only with today's cutting-edge microelectronics and new algorithms that fault-tolerant and extremely reliable and economical solutions are possible. These allow the multimedia use of the powerlines and are competitive with the costs involved with additional datalines.

A high degree of reliable and fault-tolerant powerline communication (PLC) in the automobile is no trivial matter. After all, the powerlines in an automotive wiring system are contaminated with spurious signals and interference. Each instance of turning a load on or off creates a range of interference consisting of many frequencies that impacts the powerlines' impedance. Attempts at using amplitude modulation to transmit the useful signal are doomed as they collide head on with the fact that the interfering signals have much higher amplitudes. Not to mention that the *when* of this occurring is purely random; patterns are not identifiable. This is why transmission of data over powerlines always involves inherent faults. And the information transmitted will always contain a number of errors. | **Fig. 2)**

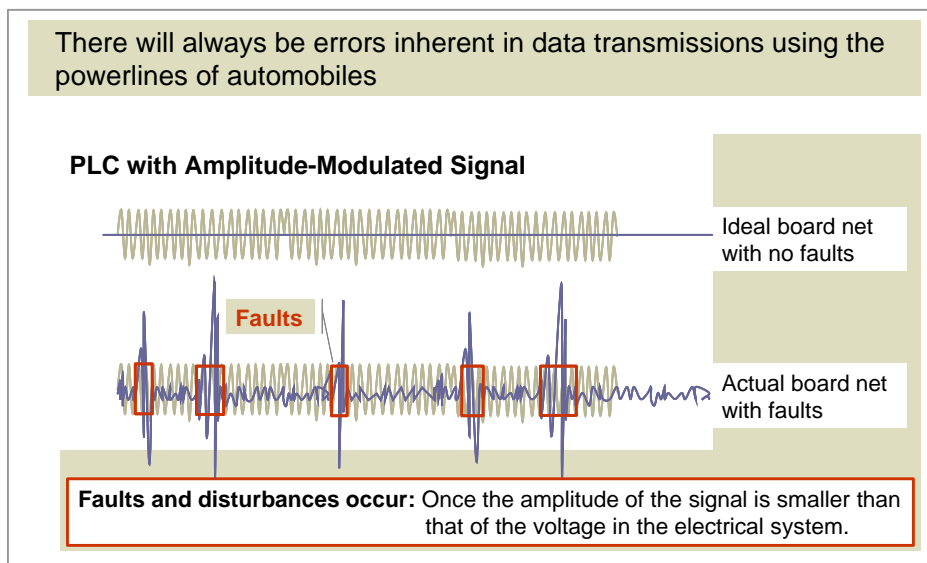


Fig.2)

Such adverse conditions appear to make powerline communication in automobiles impossible. Yet the high demands on this kind of technology remain unchanged:

- Deliver high data rates for a broad spectrum of applications
- Be safe and dependable
- Reliably identify and correct errors
- Be a competitive, economical solution

III – DC-BUS PLC Technology Architecture and Performance

The powerline communication (DC-BUS) developed by YAMAR works with phase modulation. The information is contained in the phase relationships; in other words in a specific sequence of jumps in frequency. And so, the phase is the actual information. This method not only makes the information independent from the wiring system's voltage – it doesn't matter if its 12-volt, 24-volt or 42-volt – there is no impact from amplitude disturbances. The information carrier is a sinus signal of constant amplitude. The signal is coupled onto the powerline through a capacitor. Since the amplitude is only 1 volt (peak to peak), the emission is low because the energy is low (good EMC compatibility). | **Fig. 3)**

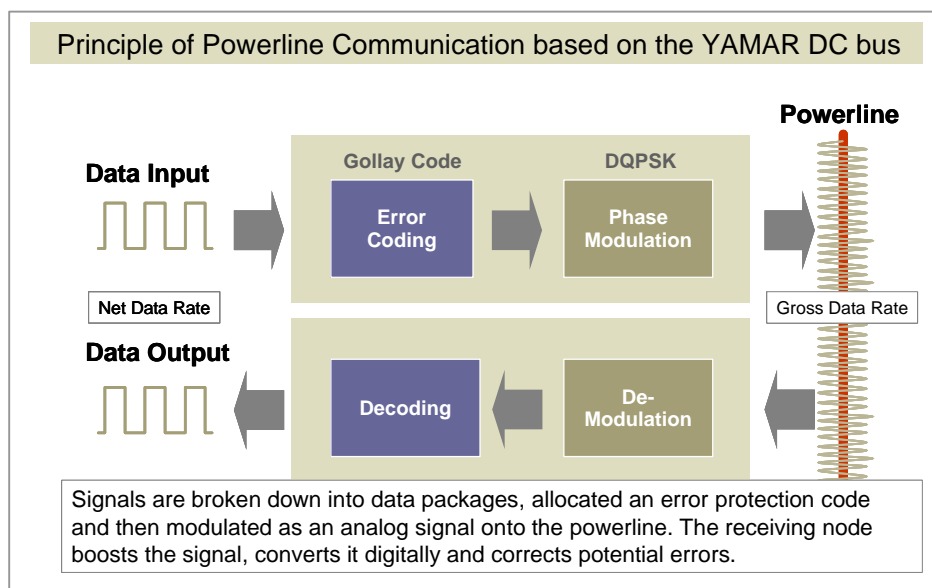


Fig. 3)

The correctional algorithm employed is so effective that it can even identify and correct errors itself when the interfering impulses reach 300 volts. The algorithm can even recognize and correct residual amplitudes of 10 mV (peak to peak). In order to better recognize an error as an error, the data volume to be transmitted is doubled: 8-bit information is pumped up to 16 bits. This means that the gross transmission rate is double that of the net data rate. What's the benefit? Even information for which 6 bits in a row is false is appropriately recognized and properly corrected. In addition, different channels can be set using frequency switches.

The first available PLC chips (SIG40 and ISL40) from YAMAR are IC components with comparatively low net data transmission rates of between 10 and 60 kilobits/second. These are what are known as chipsets in CMOS logic consisting of master and slave elements, which support buses by LIN protocol. Components of this type serve primarily for transmitting measurement data. | **Fig. 4)**

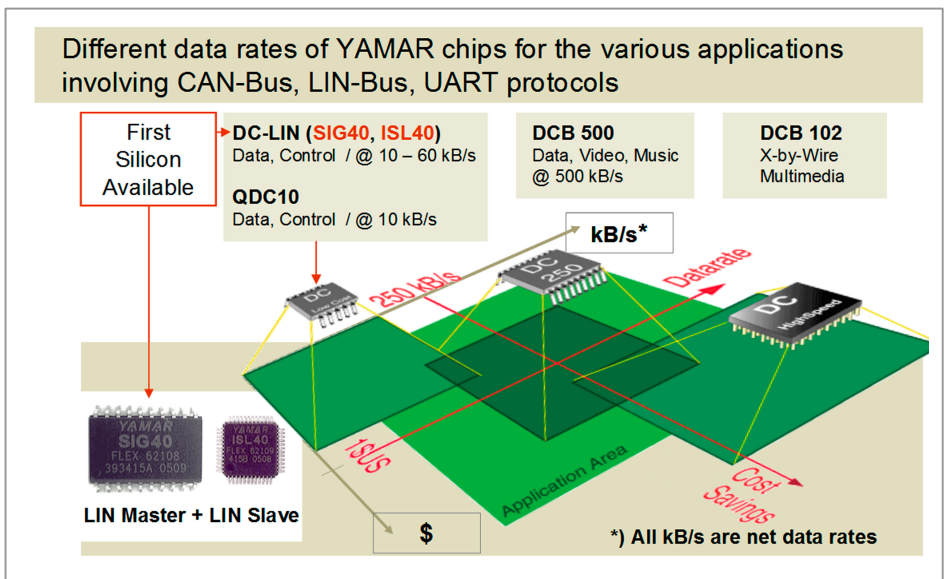


Fig. 4)

There are other IC components being prepared with net data rates of 500 kB/s for applications such as transmitting images, video or music (MP3 files). Evaluation boards are currently available.

The pricing target is about \$1 for a chipset consisting of master and slave elements having a net data transmission rate of 250 kB/s. This is about equivalent to the price of one meter of data cable with two plugs. All DC-BUS components support standard protocols such as CAN, LIN, UART and SPI.

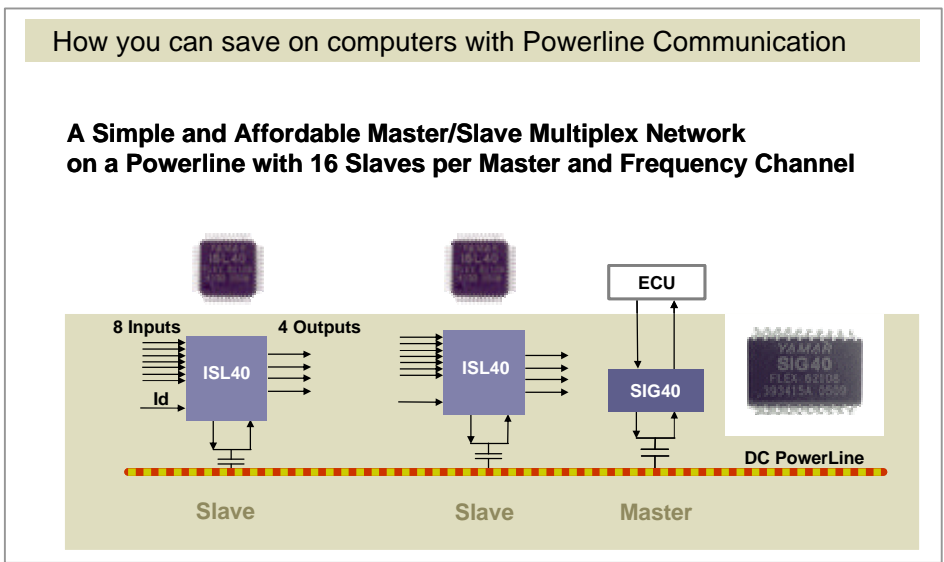


Fig. 5)

Each master element can specifically address up to 16 slaves on one frequency. A total of 32 slaves can be addressed through frequency switching. Each slave element has 8 inputs and 4 outputs. In this manner, one single master alone can switch and control remarkably large

ranges of function over the powerline without the need for a data cable. One of the things it can do when used on a truck, for example, is manage all the tail-light functions including the blinkers, side lamps and back-up lights. | **Fig. 5)**

III – Applications: DC-BUS Technology in Action

Transmitting data on the states of charge and health (SOC and SOH) from a total of 6 intelligent batteries is just one of the things PLC chips of type SIG40 and ISL40 are doing in DaimlerChrysler’s Project SPARC. These batteries are part of a three-circuit electrical system belonging to a truck/trailer combination (Actros) using the fully drive-by-wire principle. The data is conveyed through the battery posts and powerline to the respective SEM1 to SEM3 (Smart Energy Manager) control units. | **Fig. 6)**

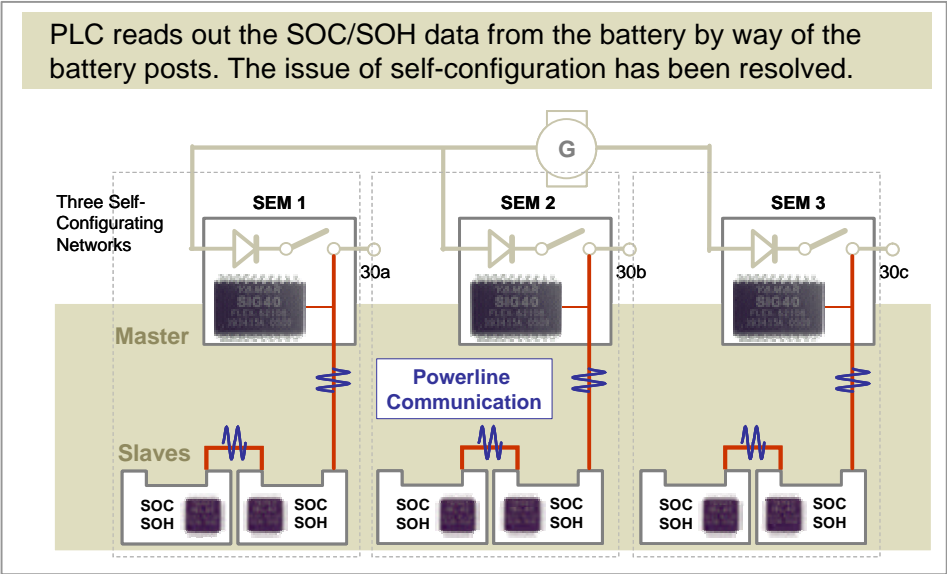


Fig. 6)

Although all master chips and all slave chips, as well as all batteries are identical with one another, the challenge of having each of the three Smart Energy Managers identifying its respective two batteries by themselves was met. This is because the power diodes allow unimpeded communication on the powerlines, so that information from all the batteries (slaves) can be received from each master (SEM). The challenge of having a self-configuring network of identical components was successfully resolved by YAMAR and iQ POWER together.

All data enters the powertrain controller (PTC) as energy vectors, which are consolidated into one vector and passed to the subordinate decision control system (DCS). | **Fig. 7)**

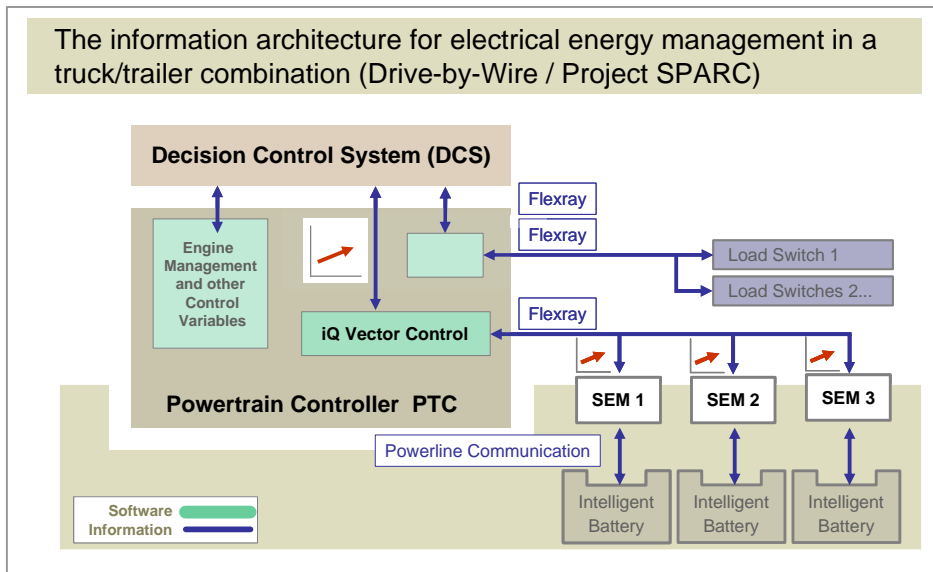


Fig. 7)

Powerline communication using DC-BUS technology opens up a tremendous range of applications: From transmitting simple signals data all the way to multimedia – from fast and simple installation of electrical/electronic components (video cameras or for sending battery-state data to the cockpit) all the way to building redundant data networks in drive-by-wire vehicles.

A Look at the Biggest Benefits:

- Economical IC components replace complex and costly wiring
- Transmits data over unlimited chassis/cable lengths
- Simple installation, even as an add-on
- Works regardless of board-net voltage (12V, 24V, 42V)
- Net data rate of up to 500 kB/s per channel
- Can implement multiple, independent networks on the powerline
- Up to 4 independent channels per chip set (master/slave)
- Supports all standard data protocols (CAN, LIN, UART, SPI)
- CSMA collision avoidance
- Integrated error correction
- Extremely high degree of error tolerance
- Enables greater freedom of engineering and design