The Vehicle Power Line as a Redundant Channel for CAN Communication

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ABSTRACT

Automotive safety applications require higher reliability than achieved by using a Controller Area Network (CAN) whose nodes are interconnected via twisted pair cables.

Using the automotive power line as a redundant communication channel for the CAN network provides increased reliability without the additional weight; cost and space required by a solution employing a second CAN network.

Clearly, the wires distributing the DC power are critical for the vehicle's operation. They are, therefore, highly robust (mechanically) and can provide a relatively fail-safe communication channel when properly used. Employing battery power lines for communications is a most challenging task. This is due to the time varying nature of the impedance, the attenuation as well as various channel noises. Moreover, these impairments are location dependent.

This paper proposes an architecture according to which a redundant physical channel for the CAN network is obtained by using the battery power lines.

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INTRODUCTION

This paper describes how power line communication (PLC) can be employed for redundant CAN communication over DC power lines. Transmitting CAN messages over the power line avoids complex cabling, thus reducing weight and greatly simplifying installation, while maintaining the CAN user format.

The CAN protocol over twisted pair physical medium is widely used in automotive applications. Fault tolerant CAN transceivers allow network operation even if one of the twisted pair lines is not functioning. However, for safety applications, communication must be robust enough to withstand potential mechanical and electrical failures not usually tended by the CAN transceiver. These include: one-wire interruption, one-wire short-circuit either to power or ground, two-wire short-circuit, termination failure [2] and various noises.

Communicating over the power line as a redundant channel for CAN messages, maintains the required communication performance and transmission delays while increasing the network reliability. The reliability level achieved by using this redundant architecture is indeed sufficient for safety applications.

From a CAN node point of view, transmitting a CAN message over a power-line, or over a CAN twisted pair, is exactly the same. In both cases the message is simply written into the so-called *transmit buffer* of the CAN controller.

REDUNDANT CAN COMMUNICATION

As mentioned above, the fault tolerance mechanism of CAN networks cannot provide reliable communication in various real cases as: disconnected nodes, stuck at dominant or recessive nodes and simultaneous interruption of both wires in the network cabling [2].
For safety applications normal operation is required in all real cases, therefore redundancy is required.

To achieve true redundant communication, a message has to be transmitted over independent channels. Thus, if a message fails to pass via one of the channels due to mechanical or electrical disruption, it will, with high probability, be correctly received via the other channel (as it is unlikely that both channels are simultaneously faulty).

Using redundant communication with the CAN protocol over two independent physical layers, requires special considerations. In traditional CAN operation, a CAN message is written to the transmit-buffer of its CAN controller. After inserting stuffing bits and other required fields such as the CRC, the CAN message is transmitted over the physical layer. When too many (as defined by the protocol) transmission or reception failures occur, a CAN node is removed from the network.

Redundant CAN communication inherently suffers from the problem that different nodes can win the arbitration over the different channels. This problem exists whether power line communication is used or second CAN channel is used for redundancy. Therefore, operating with redundant CAN channels requires a deterministic mechanism, or a network supervisor (master) to properly determine the communication and wakeup process (in which the arbitration is often exclusively used). As a result, the arbitration process is degenerated. In addition, eliminating collisions is expected to provide better utilization of the bus, while allowing redundant communication when required. Using a PLC transceiver for redundant CAN communication

A special PLC transceiver for working over DC power lines was developed. This transceiver takes into account the noise and impedance characteristics of automotive battery line. To allow high-speed operation, the PLC transceiver is a message-oriented device. It provides a fast, multi node, and low-cost means for data communication over (existing) power lines. The PLC device is designed to operate reliably in the hostile environment of the power lines, suffering mainly from impulsive noise. An arbitration mechanism with similar philosophy as the CAN generates short transmission during a dominant Identifier bit while listening to other nodes transmissions during a recessive Identifier bit. Figure 1 illustrates the arbitration process.

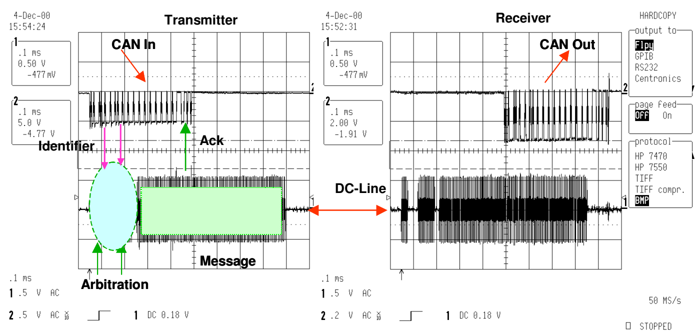

Figure 1 – Arbitration process over power lines

Initially, the device interface with its CAN controller (Host) using the CAN protocol as in figure 1. However, our experience showed that utilizing the Serial Peripheral Interface (SPI) for the redundant channel communication with the host is more efficient, allowing a Host with a single CAN interface to be used for the traditional CAN transceiver. The SPI provides fast data transfer between the Host and the PLC transceiver; limiting the latency and allowing usage of only one CAN controller. Figure 2 describes three redundant CAN processors (which are out of the scope of this paper). Each of the processors has a CAN port and a SPI port. Both of them are used to transmit and receive messages. The CAN port uses twisted pair as its physical layer while the SPI port communicates over the DC power line. Note that the latter, which is connected anyway, supplies the power to the processor units.

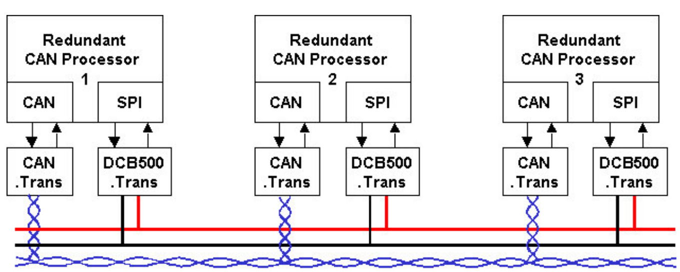

Figure 2 – Redundant CAN network

The PLC Transceiver

The PLC transceiver is a smart transceiver device. It was designed for message multiplex networking over the noisy DC power line. It operates in a network of up to 16 devices (nodes). Each device can transmit messages (of unlimited length) to other devices at two possible bit rates of 500Kbps or 300Kbps for enhanced robustness. The receiver automatically detects the message type. The device interfaces with its host micro controller via SPI, or optionally a UART. The PLC transceiver uses narrow band channels operable in selectable frequencies (channels). This allows more than one independent network to operate over the same DC wire. Some of the main parameters of the device include:
Center frequency: Selectable between 2 and 12MHz
Data transfer rate: 300Kbps or 500Kbps.

The PLC device handles the communication physical layer and part of the link layer (Modem, CSMA/CA, Channel Coding, and UART/SPI interface protocol). A Sleep mode enables low current consumption.

CAN redundancy in FP6 SPARC project.

The goal of the European sixth framework program (FP6) SPARC project is to substantially improve traffic safety and efficiency for vehicles carrying heavy goods by using intelligent x-by-wire technologies in the power-train. To provide this standardized concept, an automotive Software/Hardware platform is currently being developed. It is scalable and usable from heavy-goods vehicles down to small passenger cars and can be integrated therein [4].
As part of the project, trailers will be autonomous units in the sense that they will house their own "intelligence and control mechanism". This in turn calls for a reliable and a redundant link between the truck and its “intelligent” trailer. The PLC provides the redundant CAN communication channel over the existing DC cables at communication rates of up to 500Kbps.

CAN-PLC Message Flow

The CAN message for transmission is placed both in the CAN Tx buffer and the SPI Tx buffer. The CAN massage is handled by the CAN controller according to the CAN protocol and transmitted via the twisted pair physical layer. At the receive side the CAN controller handle the message according the CAN protocol.
The CAN message in the SPI buffer is transfered to the PLC device at high speed of 4-20Mbps (depends on the processor clock). The PLC device starts the transmission of the message over the power lines with a preamble followed by the content of the message, protected with error correction code, interleaving, and a checksum. The receiving device handles the ECC computes the checksum and transfer the message to its host. Figure 3 describes the CAN and the PLC messages.

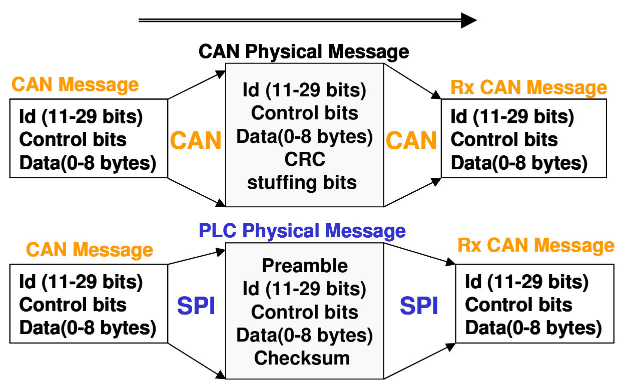

Figure 3 – CAN and PLC message construction

CAN-SPI software driver

In traditional CAN operation, both the CAN transmit and receive messages are stored in the host dedicated buffers. A CAN message consists of up to 13 bytes: 2 or 4 bytes of the identifier, up to 8 bytes of data and one byte of message length. Two drivers will allow simple interface between the host CAN transmit and receive buffers and the SPI port; The SPI-Transmit-Driver transfers the 13 bytes to host’s SPI port, which automatically activates the PLC transceiver.

Upon receiving a message over the power line, a PLC transceiver device generates an interrupt to its host. It activates the SPI-Receive-Driver that fetches (through the SPI) the message bytes and stores them in the SPI-Rx-buffer. These processes are similar to CAN transmission and reception. Additional functions such as acceptance filter may be included in this driver.

The driver also handles receive errors detected by the device receive mechanism (including checksum that is automatically added to every message by the PLC transmitter).

Error Detection and Correction

The PLC transceiver protects its data by a forward Error Correction Code (ECC) mechanism designed to overcome errors generated by typical DC line noises. . Two code mechanisms are implemented, for 500Kbps-net operation and extended error protection for 300Kbps-net operation (the actual symbol rate over the DC line is much higher the device incorporates a modified Gollay forward error correction coder/decoder with interleaving to overcome up to 6 consecutive errors . Uncorrectable errors are detected by the ECC and by a checksum that is added automatically to each transmitted message.

Latency issues

An eight byte CAN message at 250Kbps with its extensions consists of between 130 bits (not including the stuffing bits) and 151 bits. Transmitting this message over the CAN network will take between 520uS to 604uS. Same CAN message transmitted via the PLC transceiver will take between 474uS, and 565uS (when an optional extended ECC is used).

CONCLUSION

The PLC provides an alternative and redundant communication channel over the power lines for the CAN twisted pair connections. It allows efficient transfer of CAN messages via an independent physical layer.

The redundant CAN network has to be controlled by an arbitrator (master) to avoid collisions.

REFERENCES

[1] DCB500 data sheet. Yamar Electronics Ltd.

[2] Jose' Rufino. Redundant CAN architecture for dependable communication. CSTC technical report RT-97-07. December 1997

[3] Wolfhard Lawrenz. CAN System Engineering. Springer. ISBN 0-387-94939-9

[4] SPARC – http://www.eu-sparc.net/