CAN for energy efficiency in cars.

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In the light of going “Green”, one of today's major challenges for carmakers is improving the fuel efficiency to reduce the vehicle's fuel consumption and its carbon footprint [1]. The efforts to achieve greater efficiency can be obtained in different fields. Within this paper we want to highlight different methods on energy savings in the field of In Vehicle Networking using CAN bus.
Starting with System-Basis Chips (SBC) with an on-board DC/DC convertor for optimized power use compared to classical system-basis chips with linearly regulated supplies. Its deployment in the powerful Body Control Modules and other modules with more power hungry micro-controllers will bring an important gain in fuel consumption.
A further step is the use of Partial Networking to put part of the network in a low power mode. In the method described in ISO 11898-6, selective wake-up is used. After a discussion of this method, an architecture based on CAN repeater chips will be proposed as an alternative solution to obtain significant power savings.

1. Introduction.

Controller-Area-Network (CAN) networks are widely used in commercial and personal vehicles. In current cars the number of Electronic Control Units (ECU) connected to each other over a CAN network is ranging from several nodes up to 100 in premium brands. When assuming low power mode currents per node in the range of 100uA still results in a significant overall current consumption. Having a good power management per ECU and a system architecture focused on reduced power consumption will result in reduced CO_2 pollution.

2. System Basis Chips.

While today conventional SBC products are built using an on-chip Low-Dropout (LDO) regulator, the main challenge for the supply is the power/heat dissipation. For a regulated supply current of 150mA at 3.3V this power dissipation needed only to provide the regulated voltage might run up to 1.5W. With internal pass-element this power is dissipated inside the SBC housing. To reduce the power dissipation within these SBC parts while driving higher currents (typical above 250mA) the commonly used technique is the use of an external pass-element. In this case the power dissipation is distributed between the SBC and the external FET so that the useful ambient temperature range can be extended.
SBC’s with integrated power management have the advantage of better controlled power consumption compared to traditional implementation with stand-alone transceivers and power-supply components. With current technologies and power management schemes the Sleep current for the SBC is below 20µA while a Standby current below 60µA is achieved.

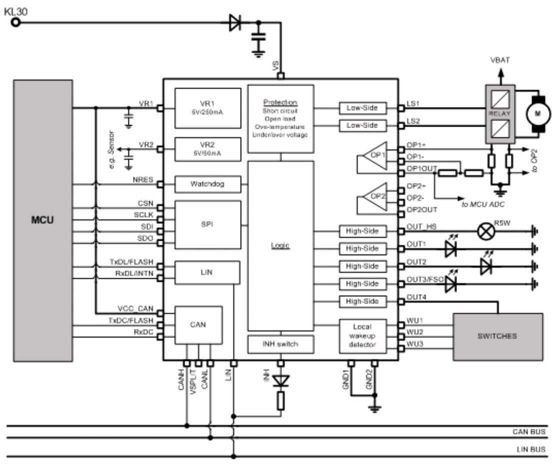

Figure 1: Example of an SBC based application using two on chip LDO's.

switch mode power supply's (SMPS) addresses not only the thermal issues but also increases power efficiency thanks to a more power efficient DC/DC conversion, while keeping the overall system cost low. System Basis Chips with integrated SMPS bring another advantage to the overall application when the correct architecture is used. As in newer cars the start-stop system has made its entrance to further reduce fuel consumption, the application needs to work with supply input voltages as low as 2.5V. Here the selection of a up-down conversion is required. For the implementation a "boost-buck" configuration is preferred.

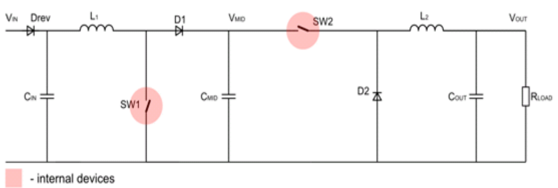

Figure 2: Principle drawing of Boost-Buck configuration in power SBC.

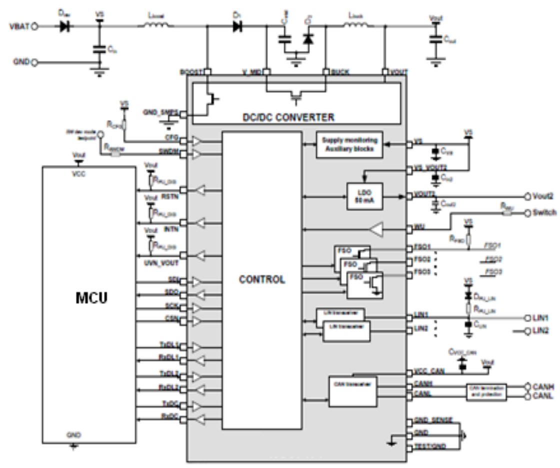

Figure 3: Example of an SBC based application using on chip LDO's and DC/DC converter.

An additional advantage of the above implementation can be seen on the low power mode. With this configuration in standby mode, having the 5V output voltage present, the internal component is supplied by the DC/DC converter and the component consumption from the battery is less than 60µA.

3. Partial Networking.

In CAN bus-systems, all nodes are connected to the same bus and see the same messages. For reduction of consumption, part of the nodes need to be put in low power mode (sleep mode). When required, these nodes need to be put to normal again (waken up) via the bus by sending appropriated messages.

Partial Networking (PN) is the common term to reference this ability to operate only a part of the network that is necessary at that specific moment while the other nodes are in low power consumption state. Under PN multiple implementations can be chosen. Here below we describe two implementation possibilities:

- Selective wake-up functionality
- Using a CAN repeater

3.1. Selective wake-up functionality.

Partial networking as described in the ISO 11898-6 [3] standard, defines one implementation method on how to reduce overall power consumption on a CAN bus. When an ECU is not required to work it can be disconnected from the CAN network as long as there is no specific command send to this specific node.

To obtain this PN function the individual nodes requires the "selective wake-up function" build in the dedicated transceiver. For this selective wake-up based on addressing the specific node, the transceiver needs following additions to the conventional ISO11898-2 transceiver:

- Incorporation of the CAN higher layers to detect the messages in the transceiver.
- Configuration registers (20 byte) and an SPI interface to microcontroller for configuration of the device.
- Precise oscillator.

This implementation results in an increased system cost. Furthermore, the implementation of PN requires a software adaptation on all nodes within the network for using this system, which brings an important burden in the implementation.

3.2. CAN Repeater.

When all nodes have to listen to these specific messages as described in the "selective wake-up functionality" approach as described above, all these nodes are consuming power and have cost drawback as described.

By introducing a bi-directional repeater on one of the modules connected to the CAN bus, we can split the logical bus into two physical parts.

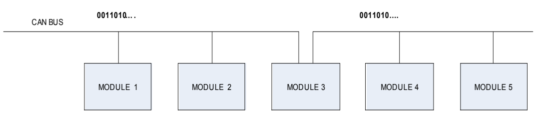

Figure 4: Modules connected to a CAN bus. Module 3 has a CAN repeater device. It repeats the data from one bus to the other bus.

Regular modules have 1 CAN transceiver that is connected to the bus and that translates the physical CAN signals to digital signals that are processed by the module's microcontroller.

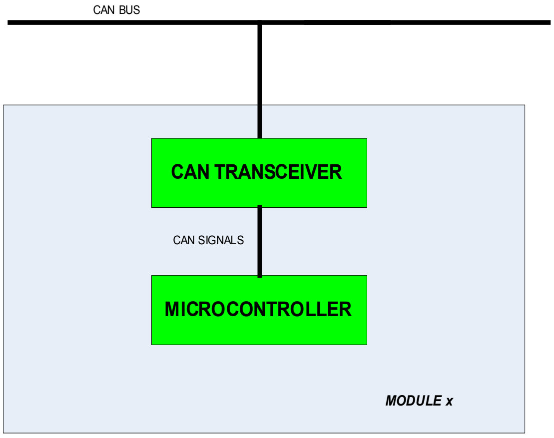

Figure 5: Non-repeater modules have a single CAN transceiver and messages are interpreted on the microcontroller.

In this special case, we introduce a CAN repeater to one of the modules. This CAN repeater also interfaces with the microcontroller in a similar way as a standalone transceiver does, but it splits the physical bus terminals into two ports. Internally in the device the signals are repeated in a bidirectional way: every signal that is put on port A is transferred to port B, every signal on port B is transferred to port A.

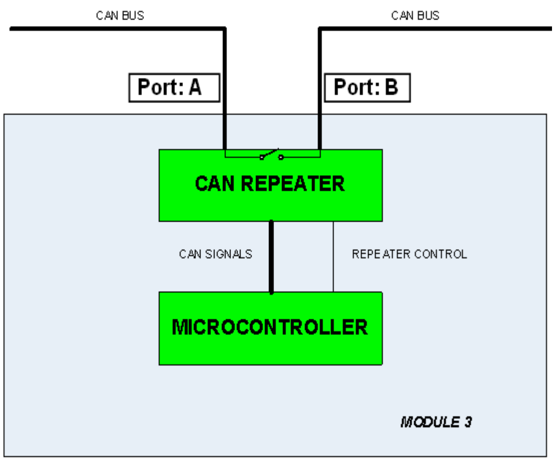

Figure 6: The module with CAN repeater.

Figure 6 shows such a setup. The CAN bus signals are interpreted in the microcontroller. Compared to the non-repeater modules, only the repeater control signals are added from the microcontroller to the CAN-repeater. Repetition of the CAN bus data is done within the repeater chip. The repeater chip itself is based on two standard ISO 11898 CAN transceiver chip IP which brings the advantage of well proven EMC performance. That means excellent robustness of CAN communication and high resistance to unwanted wake up under EMC conditions.

There are connections to disable one of the ports. This feature is used in figure 7 to disconnect a part of the network.

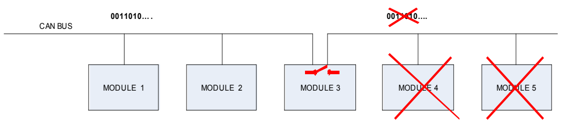

Figure 7: Shows a disconnected part of the BUS system.

After receiving a Go-to-Sleep command, the switch is opened: there is no connection with the other part of the network. All nodes on that branch can assume a (very low power) sleep state. Typical transceivers are woken up by changing signals on their bus lines. As the bus is kept quiet, there is no wake-up, even not with standard ISO11898-2 transceivers. The part of network that is in low power mode (disconnected part of the bus in Fig 7) can be activated by:

a) Commands on the active network send to the module with CAN repeater function. The repeater is enabled again and the nodes can see the bus-wake-up signal.

b) Remote wake-up function: the low-power receiver monitors its activity on the bus and if a dominant longer than a predefined time is detected, it will be send to the onboard controller. This signal can be used as wakeup in the application, reactivating the switch in the CAN repeater.

Bus faults like wire shorts to ground or to battery, for example, are not copied from one bus section to the other bus over the CAN repeater. This is an important fault tolerance feature for the so-called “hard” bus faults, which interrupt the communication. “Soft” errors with effects like increased electromagnetic emissions, thermal issues, etc. are not affecting the full network. The repeater act in this case as some kind of “isolator” for faults between the different parts of the bus.

Key benefits for the above described solution using a CAN repeater element in the network are:

- Simple and cost-effective solution as in all but one node, standard transceivers can be used, with no need for SW adaptation. Use of standard transceivers (ISO11898-2 or ISO11898-5) in combination with just one Repeater device.
- No power consumption on any of the nodes that are on the segment of bus that is in sleep mode.
- Bus fault confinement

In case required, multiple repeaters can be inserted in the CAN network to create branches.

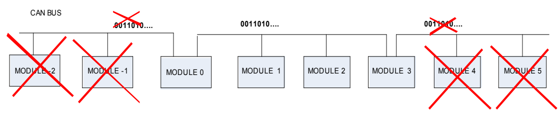

Figure 8: Extension to more nodes

The CAN repeater can even be used to build a network with multiple bus extensions, like:

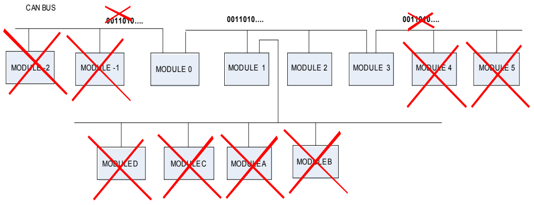

Figure 9: Repeater example for multiple sub-busses

Every repeater introduces a propagation delay which needs to be taken into account for overall topology timing calculations. Together with cabling lengths, sample point location setting, etc. this delay will determine the maximum possible communication speed.

The CAN repeater system is able to reduce power consumption at a lower system cost than with Partial Networking.

A similar technique can be used with other network system, such as LIN. There the case could even be more advantageous. Up to now there is no specific LIN Partial Networking method described. With increasing attention to reduce the power consumption, this surely can become a topic.

4. Conclusion.

The reduction in fuel consumption and, related to this, the reduction in CO_2 pollution can be obtained by different improvements to the In-Vehicle CAN network.

It was explained that introducing System Basis Chips with improved power management is a first step in reducing power consumption.

As a second step, two architectures were explained on how to reduce power consumption on nodes connect to a CAN bus by switching off the nodes when not needed and only turn on when direct addressing of the node is implemented.

Both of these Partial Networking architectures, selective wake-up functionality and CAN Repeater, where presented with drawbacks and advantages. Implementation effort and cost between the two different implementations were discussed as well as the impact on bus topology, communication speed, EMC robustness and sensitivity.

References:

[1] CAN Newsletter December 2011
[2] OEM Hardware Requirements For Partial Networking
[3] IS011898-6 Road vehicles - Controller area network (CAN) -- Part 6: High-speed medium access unit with selective wake-up functionality (2011-05-11)

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