Contactless CAN interface - A standard for aftermarket automotive

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Use of embedded controls units is still increasing in embedded systems like automotive, trucks… The industry trend is to develop distributed architecture, using embedded networks like CAN bus technology to link all together more and more parts as Electronic Control Units and functions. At the same time, there is the need to connect more and more extra consumer electronics products (telematics and infotainment systems, fleet management systems, Pay As You Drive equipment, black box for insurance…) to the original distributed electronic architecture of these embedded systems. By this way, electronic devices can get access to a lot of information from the car and offer more powerful added value functionality's within always limited costs.

Unfortunately, systems makers don't allow intrusive solutions for safety, reliability reasons and for maintaining integrity of their entire systems. So, at this moment, there is no reliable and no legal way to integrate consumer electronics devices without compromising the integrity of the vehicle's electronic system in an existing platform in aftermarket. NSI offers one way to do it thanks to it's CAN contactless technology. Such interface acts as a 100% spy and neutral solution. It extracts data's from the embedded networks (such CAN bus or other) without any electrical contact to networks medium. In this way, it's compliant to system makers requirements, waranty the original integrity of their electronic architecture. There are plenty of applications for such contacless interfacing technology: fleet management system, CAN spy analyser and tools, insurance spy equipments and other after market equipments.

This paper presents the main characteristics of an innovative CAN contactless solution: Technical presentation of the CAN Contactless interface, Reliability of the solution and Examples of application.

1 Vehicle architecture

For more than ten years, electrical vehicle architecture is based on embedded networks and especially on CAN network.

Originally, CAN was used only for engine control, but today there are a variety of CAN nodes not only for powertrain and chassis control but also for body electronics and infotainment systems. Most of the car manufacturers all over the world base their control architecture on CAN.

Today, electronics architectures are splitted in different CAN networks because of different reasons: bandwidth, reliability, functionality.

For example: engine CAN network, chassis CAN network, body CAN network, comfort CAN network, entertainment CAN network…

Each network can have a specific speed according to their dedicated requirements (100 kbits/s for a body till 1 Mbits/s for an engine network).

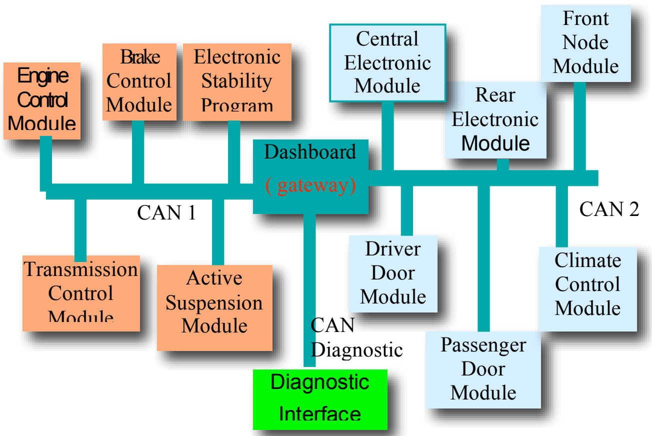
In the same way, car makers use the different physical layers available on the market: CAN High Speed or CAN Low Speed. This offers some capabilities, well suited for the network (High Speed, Fault Tolerance, Wake Up mode).

New car architectures include now sub-systems based on other networks standards. LIN technology is an example of these new low cost networks dedicated to sub-systems. Door sub-system, Climate control sub system… are now available on the market.

To link these networks all together, some E.C.U. (Electronic Central Unit) have gateways capabilities between different networks or master capabilities between network and sub-network.

Generally, all these E.C.U. are connected to the diagnostic interface through a dedicated network, through the main CAN network, through gateways… There are different topologies existing on the market.

Below, there is an example of a sample car architecture available now days.



2 Need to recover CAN datas

With these distributed architectures, most of the vehicle information: parameters, real time data, input values, output states, configuration data, system diagnostic status… are shared on these CAN networks.

All these information could be very useful to be catched on the fly from the heart of the system according to the state of the car.

2.1 Engineering phases

During these phases, system engineers are interested in analysing or recording all the data in real time to validate distributed algorithm, sub-system behaviour…

2.2 Running tests

For running tests, validation engineers want to record data’s coming from all the networks with a global time synchronisation between the networks.

These data’s are used for unit or global validation of the vehicle (inputs / outputs survey, networks behaviour, distributed algorithms, gateway performances, wake-up phases…).

2.3 Assembly line tests

Some car makers are interested in having a network recorder acting in spy mode during the whole assembly process of the car. In case of electrical or electronic problem in end of line, it will be easy to analyse and compare the recorded data.

2.4 After-sale

Intermittent and transient faults are the most difficult problems to resolve in car industry and especially when the vehicle is already delivered to the customer. After-sale technical team would like to survey some parameters of the faulty functions without changing anything in the car equipment.

2.5 Aftermarket

As described in the abstract, there is the need to connect consumer electronics products (telematics and infotainment systems, fleet management systems, Pay As You Drive equipment, black box for insurance…) to the distributed electronic architecture of these embedded systems. By this way, electronic devices could take a lot of information from the car and offer more powerful added value functionality’s within always limited costs.

3 How to recover CAN data

3.1 Integrated connectors or gateways

A first approach might be to integrate connectors dedicated to each network in the cable harness. By this way, it could be easy to connect a CAN data-logger, analyser… with the suspicious network but this solution is incompatible with automotive cost requirements.

More over, there are always risks in getting open connectors in the car. Probabilities of faults (short circuit between CAN pins) are more important and are not conceivable.

3.2 Connector insertion

Another way to recover CAN data’s is to insert a CAN derivation in the cable harness of the car. By this way, it's possible to recover data's from the network. This solution isn't compatible with the car makers constraints :

Car makers don't want aftermarket products or tools to be connected directly on the network. They want to maintain integrity of their networks for reliability and legacy reasons.

In the same way, inserting a derivation in the network changes the topology of the network. The behaviour of the global network could be modified and there are risks in multiples connections and disconnection's of additional connectors. So, this method, even if it's used today, isn't the most suitable according to development, validation, aftersale engineers.

3.3 Networks available on the diagnostic plug

Generally, there is only one CAN network available on the J1962 diagnostic plug (often engine CAN network) which doesn't allow to get all required information.

3.4 Resume

Different solutions exist to recover CAN data on the car but they don't suite neither for engineering use, neither for aftermarket applications:

There is no direct access to the system original information.

4 Contactless CAN interface

Contact-less solution is the ideal solution: having a CAN plug, electrically isolated from the car CAN network medium, easy to install in a car, able of spying CAN frame and signal (or other network standard like LIN…) without specific adaptation to the speed or to the physical layer of the network.

Such a solution will be compatible with the car maker requirements, easy to use for engineering applications and without extra cost for aftermarket applications.

Because this solution is the same for all CAN architectures, it avoids long and costly adaptation process and requalification of entire system for new adaptations.

5 Technical solution

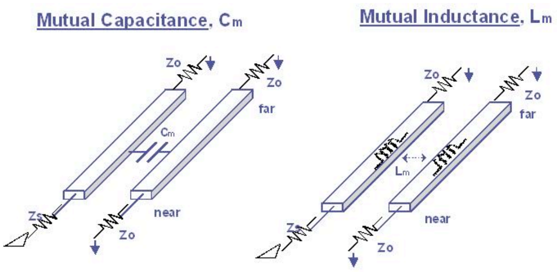
The solution is based on using **crosstalk induced noise**.

Crosstalk is the coupling of energy from one line to another through:

- Mutual capacitance (electrical field)
- Mutual inductance (magnetic field)

Then, the generated signal is processed in order to create an image of the CAN signal available on the source line.

5.1 Crosstalk induced noise



5.2 Mechanism of coupling

The circuit element that represents this transfer of energy are the familiar equations:

For mutual inductance: $V_{Lm} = L_m \frac{dI}{dt}$

The mutual inductance will induce current on the "victim" line opposite of the driving current (Lenz's law).

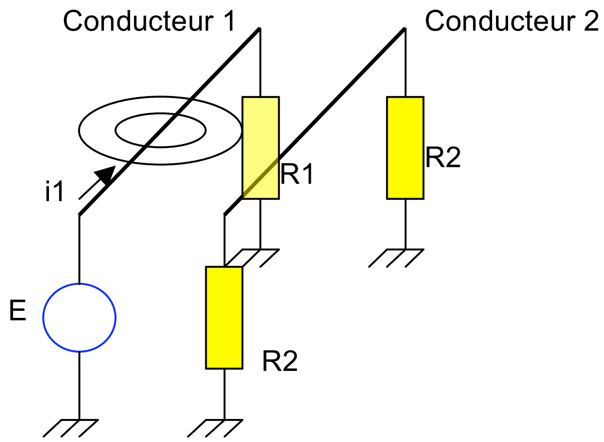
For mutual capacitance: $I_{Cm} = C_m \frac{dV}{dt}$

The mutual capacitance will pass current through the mutual capacitance that flows in both direction on the "victim" line.

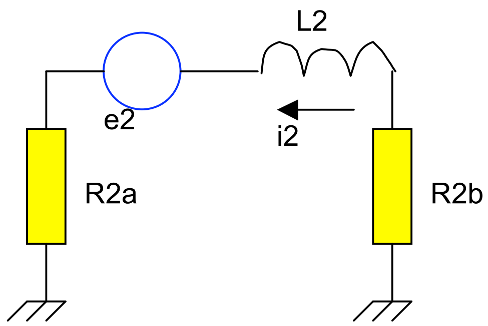
For maximum frequency 1 Mbits/s (500 kHz frequency), the corresponding wave length is around 600 meters

In relation to the maximum cable length used in car CAN networks (less than 100 meters), calculations for mutual inductance and mutual capacitance can be dissociated.

5.3 Inductive crosstalk



"Conducteur 1" represents the main network

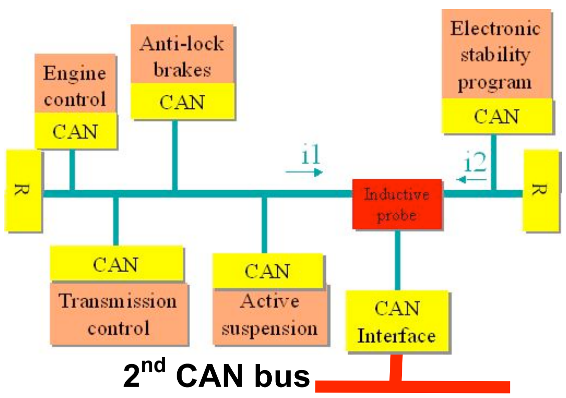


Equivalent schematic

Generated voltage is: $e_2 = -j\omega M_{12} i_1$

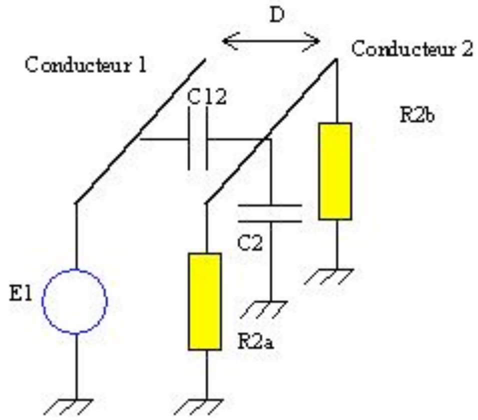
The limit to this solution is the probe position in regards to the different ECU.

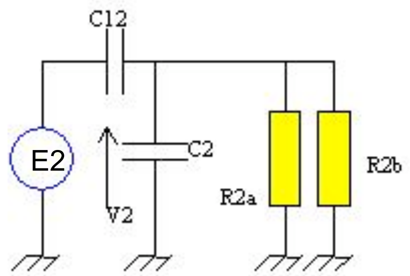
Because the signal level depends on the current sense, the probe will have some limitation during arbitration phase or acknowledgement phase depending on its position in regards to the E.C.U.



In the figure above, when the active suspension ECU node sends a frame (i1), if the acknowledgement is sent by the ESP ECU node (i2), the output of the inductive probe will generate a CAN error frame on the 2nd CAN bus.

5.4 Capacitive crosstalk





Equivalent schematic

The value of the measured signal is :

$$V_2 = E_1 \frac{C_{12}}{C_2 + C_{12}} = E_1 K$$

In order to have good performance on the capacitive probe output signal, we have to limit C2.

5.5 Resume

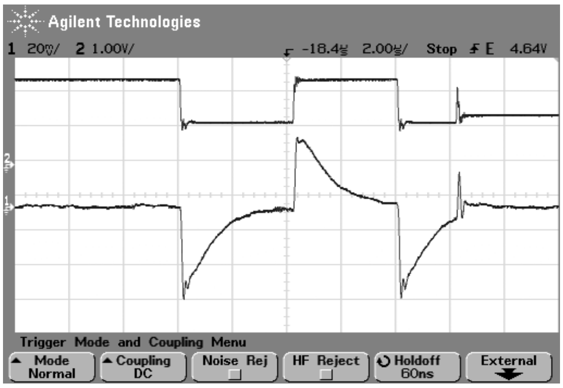
According to the theory explained above, to the limitations of the inductive probe and to the experimental tests done around these two principles, NSI has chosen to develop and to patent a capacitive smart probe.

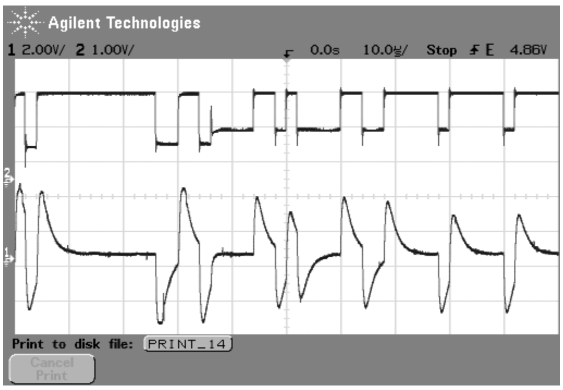
6 Practical tests

6.1 Probe definition

Signals waveforms may completely differ, depending on the probe technology, the chosen component values for the electronic filter and amplifier, and so the signal processing (in order to rebuild CAN source signal) may become more or less complex and efficient.

Below are the “screen copy” coming from 2 different electronic probes. Signals are very different and the choice will influence the performance of the signal processing done to rebuild the CAN network in the smart probe solution.





6.2 Position of the probe

The probe can be installed all around the CAN network. This kind of probe is independant of the network topology because this is an capacitive probe compared to a inductive probe.

In this way, it’s easy to install in the car without knowing the exact Network topology.

6.3 Differential probes for CAN network

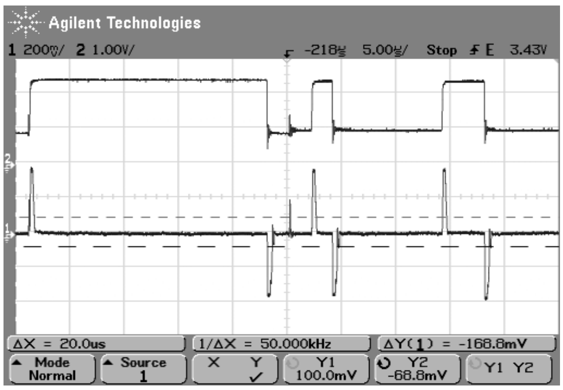
As for the CAN protocol, efficiency is improved by using signals coming from two different probes in a differential mode.

In this way, a differential signal is rebuilt by subtracting signals from these two probes (one for CAN High and one CAN low) during the signal processing

6.4 CAN signals influence

Additional filters have to be inserted in the “signal processing” to be able to treat the different CAN type. for event like arbitration with ground shift between the 2 E.C.U.

All the know how in such an efficient smart contactless probe consists in the adequate filtering, amplifying and adaptation of the probe to the medium but over all a set of extra “smart triggering strategies” for CAN specifics events detections and processing such as acknowledgment sequence or arbitration effects…



6.5 Efficiency

Depend of the probe technology, the efficiency of the probe could reach more than 99%.

7 Applications for aftermarket

This contacless CAN interface is a perfect solution to answer to the different questions about all these new devices:

How to recover information from CAN networks, without any electrical, protocol interference?

How to recover information from CAN networks, without any extra cost or modification on the standard cable harness?

7.1 Fields of application

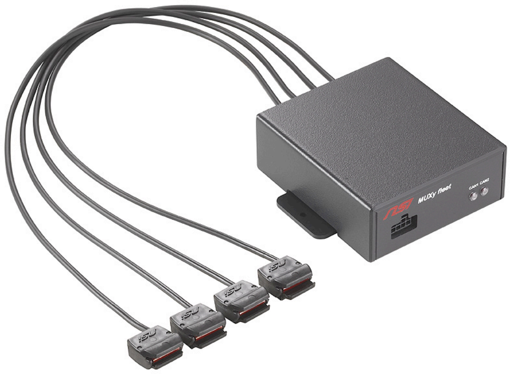
The field of applications is very open. Before CAN contactless interface concept, you needed to have a wire connected on each required signal (rpm, vehicle speed, doors, brake…)

With such an interface, you only need to connect the probes on the right CAN network. Multiple applications are available:

- Alarm system to obtain door states
- Fleet management to integrate vehicle speed, rpm, detailed fuel consumption…
- Hands free kit to adapt the signal according to speed, rpm
- Black box recorder for after sale in case of transient fault
- Pay As You Drive insurance to get the best and most pertinent information on the way of drive through the original CAN signals from the car
- Special vehicles (ambulances for example) based on standard chassis with dedicated E.C.U. Contactless CAN interfaces will give CAN information
- Car trails to provide lamps, brake, indicators information whatever the car is

7.2 Example

Below is a fleet management product, able to recover data's from two different buses: (rpm value coming from engine network and door and seat belt states coming from body network)



8 Conclusion

A new age for picking up and extracting data from the heart of any existing electronic architecture using direct coupling on CAN bus systems is coming. It's widening field of applications keeping the original integrity of the system, thanks to this smart contactless approach avoiding costly and time consuming adaptation and system re-qualification.

"Integrity for a direct access to the original information in the heart of your system"

References

[1] Intel presentation: crosstalk Overview and modes

[2] Gabriel Vasilescu: bruits et signaux parasites (Dunod édition)