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Safety Reliability Enhancement in Fault tolerant Automotive Embedded System

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Abstract: Reliability is control and prevention of failures to reduce failure and improve operations by enhancing performance with system-level analysis and modelling are needed not only for predictability and comparability when partitioning end-to-end functions at design time levels of reliability. Reliability numbers by themselves will not motivate improvements, performance of two fault tolerant mechanisms dealing with repairable and non-repairable components that have failed. The improvement in the reliability and safety of a system with repairable components with respect to the fault tolerant systems under study correspond to a flexible arrangement of fault tolerant units (FTU's). SFAS (Safety Fault tolerant Automotive Systems) and ECU are being compared to achieve effective results. Reliability principles are discussed which assist system improvement for reducing the high unreliability. CAN Controllers are used in automotive for fault tolerant embedded system. The existing reliability enhancement models are emphasizing various redundancy techniques both in hardware and software without focusing a formal way of recovery time minimization from the affected or degraded states in the automotive systems.

Keywords: Automotive Embedded Systems, SFAS, FT CAN

I. INTRODUCTION

Although the controller area network (CAN) protocol was originally introduced for automotive applications, it is now widely used in process control and many other industrial areas. In comparison with earlier protocols (and standards such as "RS-485"), CAN is easy to use and provides more hardware support for error detection/recovery. As a consequence of its popularity and widespread use, most modern microcontroller families now have one or more members with on-chip hardware support for this protocol. This means, in turn, that FT CAN networks can now be implemented at very low cost. These embedded systems are task specific computing or controlling units. These systems are growing in number and complexity with addition of new functionality and features to modern automobiles. Designing and developing such automotive embedded systems requires a structured approach and a very well defined set of guidelines facilitating this process. The remaining nodes, upon receipt of this message, start local timers (each with different values), which upon expiry allow local tasks to be executed and messages to be, transmitted in different timeslots on the network. However this type of "domino" architecture lacks scalability, as the authors note that "a Flex CAN network for a safety-critical system always has to be characterized by a small number of nodes."

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If we are to develop reliable embedded systems using CAN, then we need to ensure that we can achieve reliable group communications. This means, for example, that when one node transmits a message, all nodes must receive the same message. One deficiency with CAN is that this condition may not always be satisfied, [1],[2]. Most notably during the detection of end of frame (EOF)sequences. This problem can arise as follows. CAN receivers achieve consensus that the accepted message is valid by processing an error-free sequence of bits up to the sixth bit of the EOF sequence. At this point, the receiving CAN controllers accept the message. The sender, however, validates the transmission at the very last bit of the EOF Potential problem [3]. If the subset of receivers detects an error in the sixth bit of the EOF sequence, they will subsequently reject the message and begin transmission of an error flag in the seventh bit of the EOF. The remaining receiver nodes will already have accepted the message; thus, an inconsistent delivery has arisen. Under normal circumstances, the sender will queue the message for retransmission; therefore, the possibility of inconsistent message duplicates (IMDs) or inconsistent message omissions (IMOs) arises. Previous studies have shown that the probability of this situation occurring in normal CAN is highly dependent on the bit rate, the nature of the bus traffic, and the number of nodes connected to the bus. The proposed software solutions have been adopted, in some cases, by the protocols described in the previous section; however, it should be noted that software solutions generally have bandwidth and processing overheads involved [4]. CAN, which stands for Controller Area Network, is the serial communication protocol internationally standardized by ISO. The automobile industry has hitherto witnessed the advent of various electronic control systems that have been developed in pursuit of safety, comfort, pollution prevention, and low cost. These control systems, however, presented a drawback in that since the communication data types, required reliability, etc. differed between each system, they were configured in multiple bus lines [5][6], resulting in increased wire harnesses. Therefore, the need arose for reducing the number of wire harnesses, transferring large amounts of data at high speed and so on. To meet the need, BOSCH, an electrical equipment manufacturer in Germany, developed CAN in 1986 as a communication protocol for automotives. Thereafter, CAN was standardized in ISO 11898 and ISO 11519, establishing itself as the standard protocol for in-vehicle networking in Europe now. . Today, CAN is widely accepted for its high performance and reliability, and is used in a broad range of fields from FA devices and ships to medical and industrial equipment. CAN and the other communication protocols developed concurrently made it [14][15].

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II. IMPLEMENTATION OF FTCAN IN AUTOMOTIVE

The Fault Tolerant controller area network (FT CAN) protocol was originally introduced for automotive applications but is now also widely used in process control and many other industrial areas. The present requirement a low-cost redundancy-management scheme for replicated FT CAN channels that helps to ensure that clocks (and, hence, tasks) on the distributed nodes remain synchronized in the event of failures in the underlying communication channels, without the need for expensive or proprietary interface electronics. We argue that, when using this framework with duplicated channels, the probability of inconsistent message delivery drops to acceptable levels for a wide range of systems. Through an analysis of the protocol and a case study, we conclude that the creation of reliable, low-cost, distributed embedded systems using FT CAN is a practical possibility. The planned deployment of X-by-Wire technologies is leading the automotive industry in the world of safety-critical applications. More precisely, the design of such systems must take into account the dependability of two kinds of requirements[18][19]. On the one hand, safety, the absence of catastrophic consequences, for the driver, the passengers and the environment, has to be ensured and on the other hand, the system has to provide reliable service and be available for the solicitations of its users. It consists of Display unit, FT CAN Mother Board, Fault injection Board, Fault Injection Board, Battery, Power supply, Microcontroller(MC 33889) .If there is any fault in the vehicle it will find out the actual fault fault occurred and display it to the person who is driving and also control the accelerator and brake.

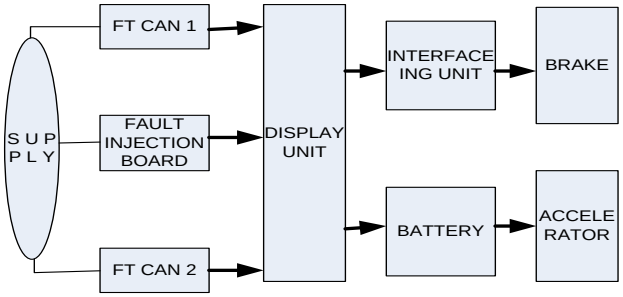

Fig I. Block Diagram of Automotive Embedded Systems

The block diagram consists of two FT CAN‘s. The FT CAN 1 is connected with the brake pedal and accelerator pedal. The one end of the FT CAN 2 is connected with the main power supply. The other end of the FT CAN 2 is connected to the display unit and the FT CAN interfacing unit. The interfacing unit is connected to the battery and the battery is connected to the wheel. Both the FT CAN‘s are connected by the fault injection board in which the faults are being injected. Although CAN was primarily intended to support event-triggered communications between unsynchronized nodes, time triggered communication which has a number of benefits may be enforced, if due care is taken at the system design stage. A number of hardware- and software-based protocol extensions and modifications have been proposed to enable time-triggered communications on CAN. These tend to rely on the use of a global clock that, in turn, supports a time division multiple access (TDMA) message schedule. For example, Turski describes a distributed clock synchronization methodology with a potential resolution of bit time, 1 using a combination of hardware and software. Pimentel and Fonseca describe a time-triggered system that, although it does not utilize a global clock, controls a cycle of communication via a synchronization message sent by a primary message producer with an accurate clock.

III.ANALYSIS OF SAFETY COMMUNICATION IN FAULT TOLERANT AUTOMOTIVE SYSTEMS

Different modes of communication in fault tolerant in automotive being analysed in technical specifications SFAS (Safety Fault tolerant Automotive Systems) the specific requirements of the different automobile domains have led to the development of a large number of automotive networks. CAN, TTP/C, Flex Ray, media-oriented system transport, one of the important requirements of an automotive communication system is fault-tolerance. The SFAS is followed with following tables I and II assumed true as ‘1’ false as ‘0’ in between as ‘#’.

Table I. Usage of Different Automotive Network

USAGE	CAN	TTCAN	Flex RAY
Chasis	1	1	0
Airbags	1	0	0
Power train	1	1	#
X-by-wire	#	1	1
Multimedia	0	0	0
Telematics	0	0	0
Diagnostics	1	#	#

Table II. Requirments of Different Automotive Network

REQUIREMENTS	CAN	TTCAN	Flex RAY
Fault tolerance	#	#	1
Determinism	1	1	1
Bandwidth	#	#	1
Flexibility	1	1	1

In automotive CAN (Controller Area Network) is widely used. CAN on a twisted pair of copper wires become an ISO standard in 1994 in Europe for data transmission in automotive applications, due to its low cost, its robustness and the bounded communication delays. CAN possess some fault-confinement mechanisms aimed at identifying permanent failures due to hardware functioning at the level of the micro-controller, communication controller or physical layer. The scheme is based on error counters that are increased and decreased according to particular events. The main drawback is that a node has to diagnose itself, which can lead to the non detection of some critical errors. Without additional fault-tolerance facilities, CAN is not suited for safety-critical applications such as future X-by-Wire systems [7]. For instance, a single node can perturb the functioning of the whole network by sending messages outside their specification (i.e. length and period of the frames).

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A framework to provide selective fault-tolerance for messages with various fault-tolerance requirements scheduled on CAN is proposed in [8]. The set of messages are analyzed off-line and scheduling attributes are provided that ensures feasible transmission of messages as well as retransmissions upon error occurrences that satisfy the fault-tolerance.

CAN standard are being used for TTCAN but, it requires that the controllers have the possibility to disable automatic retransmission of frames upon transmission errors and to provide the upper layers with the point in time at which the first bit of a frame was sent or received. The key idea is to propose a flexible time-triggered/event-triggered protocol. TTCAN defines a basic cycle as the concatenation of one or several time-triggered windows and one event-triggered window. Though TTCAN is built on a well-mastered and low-cost technology, CAN, does not provide important dependability services such as the bus guardian, membership service and reliable acknowledgment. It does not provide the same level of fault tolerance as TTP and Flex Ray, which are the other two candidates for x-by-wire [9]. Strong points of TT-CAN are the support of coexisting event- and time-triggered traffic together with the fact that it is standardized by ISO. It is also on top of standard CAN which allows for an easy transition from CAN to TT-CAN.

Flex Ray configured as a bus, a star or multistar. It is not mandatory for each station to possess replicated channels or a bus guardian, even though this should be the case for critical functions such as the Steer-by- Wire [10]. It also provides fault tolerance by distributed time-triggered synchronization and error containment on the physical layer through an independent bus guardian. Flex Ray allows both time-triggered and event triggered communication by means of a communication cycle, where a time-triggered (static) window and event triggered (dynamic) window are concatenated. The event-triggered window uses a technique called Flexible TDMA (FTDMA) to provide event triggered behaviour without collisions. According to the Flex Ray specification [11] a frame contains a 24 bit CRC checksum to ensure the integrity of the frame transmission. To allow a single communications system to support the diverse needs of automotive applications across different application domains the consortium decided to introduce a concept of scalable fault-tolerance. Scalable fault-tolerance aims at allowing Flex Ray to be used economically in distributed non fault-tolerant systems as well as in distributed fault-tolerant systems. The clock synchronization algorithm supports fault-tolerant as well as non fault-tolerant synchronization. For fault tolerant synchronization this algorithm considers the transient / permanent fault class as well as the symmetric / asymmetric fault class [12].

IV. CAN SPECIFICATIONS OF AUTOMOTIVE ECU

Various vehicle buses for different tasks of communications between ECU are used today according to their area of application (Navet, 2008). These embedded networks have both increased the functionality and decreased the amount of wires. However, the usage of different wires for the different networks still has the disadvantage of heavy, complex and expensive. The local interconnect network is used in on-off devices such as car seats, door locks, rain sensors, the control area network (CAN, medium data rate) developed by BOSCH, is currently the most widely used vehicular network. A typical vehicle can contain two or three separate CAN networks operating at different transmission rates, from 125 Kbps up to a higher-speed at 1 Mbps for more real-time-critical functions. The Flex Ray is proposed for X-by-Wire applications which require higher data rate (10Mbps) and safety. Flex Ray is a fault-tolerant protocol designed for high-data-rate, advanced-control applications. X-by-wire systems replace the mechanical control systems with electronic component. Automotive industry a great impact is represented by the testing/ measuring/ validating process of products. The future of these processes is based on automation and execution time reduction. With the growth of the modules that are automatically tested the time allocated for product design can be decreased. In the beginning of the automotive industry in a city car there were just a few ECUs responsible for implementing important functions in the vehicle like: board computer, start engine, management for fuel injection or comfort functions. Nowadays, in automotive industry one ECU is responsible for one or more functions as shown in Figure II. This was the reason why the answer to the needs of a standard communication protocol between these ECUs was first given by the Robert Bosch GmbH in 1983, while the official standard was launched in 1986. In 1992 the standard for control area network (CAN) communication protocol 2.0 [16][17].

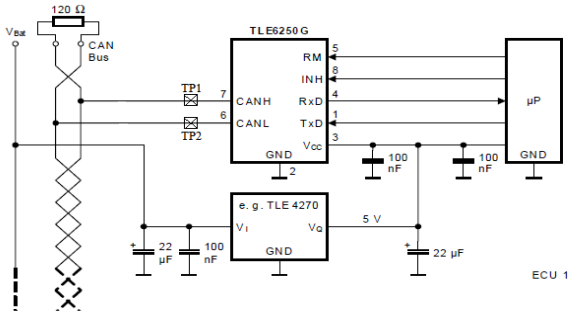

Fig II. Can Specifications For Automotive Ecu

VCAN_H & VCAN_L are the bus voltages, CAN_L (L=low) and CAN_H (H=high) with respect to ground 25]. A first TC is to determine their level in the two logical states of the CAN circuit, that is in the recessive and in the dominant states. In the recessive state, VCAN_H & VCAN_L are fixed to the average voltage level, depending on termination of the CAN bus. V_{diff} represents the differential voltage between the two CAN lines. Dominant state means that value for V_{diff} is higher than a minimum threshold measured during a dominant bit. When another ECU is connected to the CAN bus and the communication is enabled in the transmitting/receiving state, then the condition for a dominant bit is fulfilled. When all ECUs are in idle state, then the recessive state/mode is present and no communication is available. R_{diff} – represents the differential internal resistance, measured during a recessive state when a CAN node is disconnected from the CAN bus as shown in fig III and IV. Mathematically can be expressed as $V_{diff} = V_{High} - V_{Low}$.

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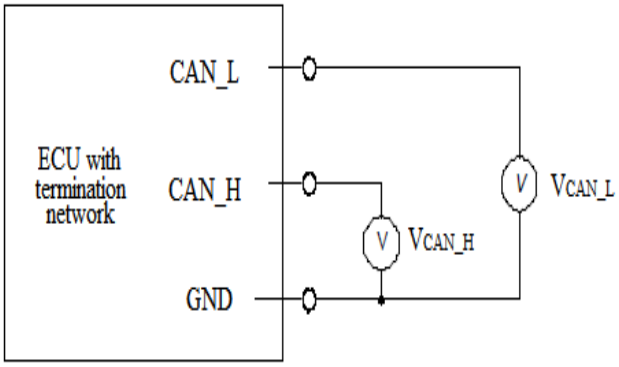

Fig III. Voltage Difference Measurement

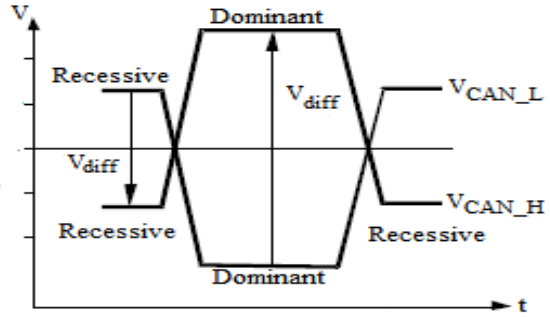

Fig. IV Physical Voltage Representation

Other test cases include Vdiff value measurement in the recessive and dominant states. Of course, it is also important to see the front details of the voltage signals, like rise time, fall time and bit time/frequency for a dominant bit.

V.RELIABILITY ANALYSIS OF AUTOMOTIVE MAINTENANCE

In car maintenance scheduling and performance control, researchers have mostly dealt with problems either without maintenance or with deterministic maintenance when no failure can occur. This was unrealistic in practical settings. In this work, a statistical model was developed to evaluate the effect of corrective and preventive maintenance schemes on car performance in the presence of system failure where the scheduling objective is to minimize schedule duration.In this, good bounds are available for the problem of minimizing schedule durations, or the make span. Graham provided the worst-case bound for the approximation algorithm, Longest Processing Time, and Coffman, Garey and Johnson provided an improved bound using the heuristic, multicity. By combining these, Lee and Massey were able to obtain an even tighter bound. These studies, however, assumed the continuous availability of machines, which may not be justified in realistic applications where machines can become unavailable due to deterministic or random reasons. It was not until the late 1980's that research was carried out on machine scheduling with availability constraints. In a study, Le considered the problem of parallel machine scheduling with non-simultaneous available time. The primitive distance specified from the company was not matching the distance calculated from the statistical analysis based on the real data collected from the work shop. It was found for most of the automobile systems, 15000 -20000km was found to perfect distance for scheduling preventive maintenance to guarantee the reliability and the availability of the automobile for operation. Early stage long ago where the electronics and soft-ware architectures of product lines are evaluated and selected. The critical architecture-evaluation and -selection design-process phase affects profoundly a product line's cost performance, and quality. Architecture selection typically is performed years in advance of subsystem development and integration. In this process, models of the functions and possible Maintenance is often perceived as the root of reliability issues are most true roots of reliability problems occur upstream of maintenance departments as shown in Figure II By using ladder model the different stages are elaborately explained as follows.

a) Reactive Stage: The goal is to restore system to proper condition as failures occur. It is a fix when failure strategy occurs. Proficiency is demonstrated when repairs are accomplished in the minimum amount of time. Nearly all problems are viewed as maintenance problems. Reliability awareness programs commence with complaints of too many failures.

b) Preventive Stage: The maintenance goal is control of planned maintenance activities rather than allowing unplanned system breakdowns. Reliability awareness of performing preventive solutions for the physical architecture must be defined and matched to evaluate quality and select the best possible hardware platform with respect to performance, reliability, and cost metrics and constraints [13]. The reliability being justified in realistic applications as shown below the figure maintains of all stages being discussed.

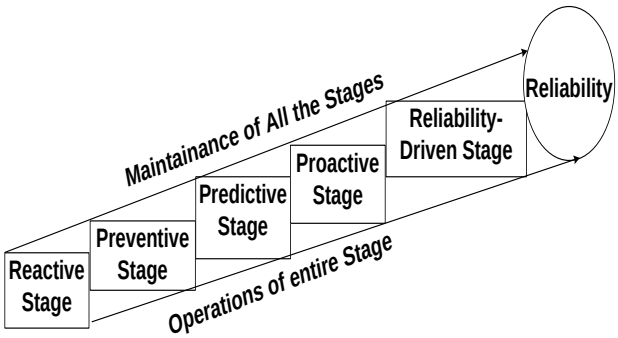

Figure V. Reliability Development Stages

Maintenance task at specific intervals helps realize inherent system reliability. At this awareness stage, much reliability work is busy work with the expectation that no machine is allowed to fail while in service by performing good maintenance as a planned event elimination of system break-downs by concentrating on best maintenance practices to reduce failures and improve availability by doing things in maintenance correctly to avoid failures.

c) Predictive Stage: The maintenance goal is elimination of system outages by use of technology to measure machine conditions reliability techniques are used to predict system failures and forecast remaining equipment life. Reliability awareness of performing predictive maintenance task at or near the end of life achieves maximum life from the system and accepts the concept that equipment fails in a probabilistic manner.

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The reliability concepts of predictive maintenance understand that careful observations must be maintained at periodic intervals to discover impending problems. At this reliability awareness stage, much of the reliability work is considered predictive maintenance is performed by operations.

d) Proactive Stage: The maintenance goal is application of predictive, investigative, and corrective technology to extend equipment life and eliminates reactive maintenance efforts. Proactive maintenance efforts involve technology for: root cause failure analysis, precision rebuild and installation, performance specifications for new and reworked equipment, certification and verification of rebuilt system, design modification of substandard system, and gathering and analysing failure data. This stage results in engineering results with technology. Reliability awareness of how engineering technology is used, often euphemistically called reliability. Reliability is often inferred by consideration of mean times to failure.

e) Reliability-Driven Stage: The maintenance strategy is a balanced integration of the previous four stages. It emphasizes elimination of breakdowns in the system which disrupts Reliability awareness at this stage is high and the cost of failures is clearly identified as a major opportunity for improvement by working the numbers to justify improvements. Reliability of equipment is quantified and reliability of processes is quantified. As reliability is improved, failures decline, availability improves, and operations proceed smoothly without the need for squeezing the last minute from each repair job because the failures are few. Reaching the reliability-driven maintenance stage requires considerable teamwork, which can only be accomplished by changing the culture in the organization. The reliability emphasis must be a conscious through ladder Identifying problems by different issues and establishing a reliability target in Figure II is precarious as it can easily roll from neutral stability position to lower levels of reactive stages.

The relation between speed and angle are being shown on the above graph and the graph is based on the readings taken from the CAN controller fault tolerant embedded automotive kit .As per the graph the angle of the accelerator position the speed increase the relation of the acceleration and speed given by A directly proportional to speed but after some time when it reaches to maximum position the relation is show above table III and figure VI that it maintains constant speed so that the acceleration position is constant at high speed there by the graph also looks as steady state.

Table III. Reading position of Angle & Speed of Accelerator

Position of Accelerator	Speed of the Wheel
0	0
1	200
2	240
3	260
4	300
5	340
6	360
7	380
8	400
9	440
10	460
11	480
12	500
13	520
14	550
15	580
16	610
17	640
18	660
19	700
20	720
21	780

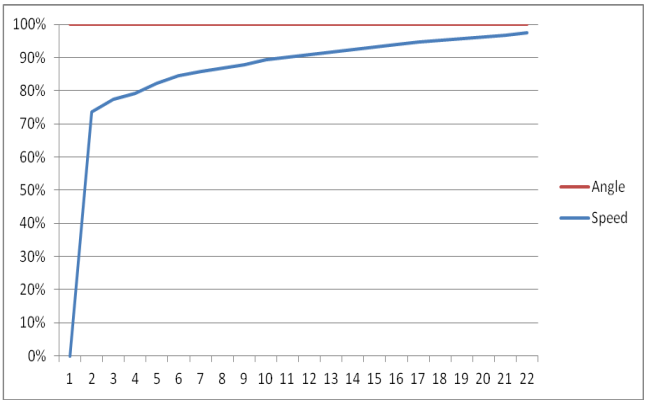

Fig. VI. The Relation of Angle and Speed of Accelerator

The Higher reliability reduces the cost for equipment failures that decrease production and limit gross profits from plants operating at maximum capacity as with commodity products and high demand proprietary products. Boosting reliability improves performance. The clear reason for improving reliability is spelled with one word: money. We speak of reliability, but we measure failures. Failures demonstrate evidence of lack of reliability. Reliability problems are failures, Failures in most continuous process industries are measured in downtime for the process. Similarly, failures are also cutbacks in output because cutbacks fail to achieve the desired economic results from the process or equipment. Most people comprehend loss of reliability from equipment downtime. Fewer people can define when a cutback in output grows into a demonstrated failure. Definition of failure, which leads to a need for reliability improvements are driven by money considerations. A lot of time has been spent on developing procedures for estimating reliability of electronic equipment. There are generally two categories: (1) predictions based on individual failure rates, and (2) demonstrated reliability based on operation of equipment over time. Prediction methods are based on component data from a variety of sources: failure analysis, life test data. For some calculations (e.g. military application) MIL-HDBK-217 is used, which is considered to be the standard reliability prediction method. “Reliability Prediction Procedure for Electronic Equipment.”

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Both of these prediction methods have several assumptions in common, e.g. constant failure rate, the use of thermal and stress acceleration factors, quality factors, use conditions Further here discussed about reliability elaborately.

VI. CONCLUSION

In the current state of practice, automotive embedded systems make widely use of fault tolerance (e.g., shielded CAN or transmission support), fault-detection (e.g., watchdog ECU that monitors the functioning state of the engine controller, check whether a data is obsolete or out-of-range) and fault confinement techniques (e.g., missing critical situation are reconstituted on the basis of other event and more generally, specification and implementation of several degraded functioning modes). Redundancy is used at the wheel angle but seldom at the ECU level because the criticality of the functions does not absolutely impose it. Some future functions, such as brake and accelerator, are likely to require active redundancy in order to comply with the acceptable risk levels and the design guidelines that could be issued by certification organisms. For critical functions that are distributed and replicated throughout the FT CAN, the system will play a central role by providing the services that will simplify the implementation of fault-tolerant applications. The methodology presented in this paper allows the evaluation of safety-reliability functions of any distributed embedded system design to be performed quickly and accurately. The Common techniques for fault handling are fault avoidance, fault detection, masking redundancy, and dynamic redundancy. Any reliable embedded system will have its failure response carefully built into it. Safety Fault tolerant Automotive Systems are being discussed and future technical enhancement can be done in this concern.

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