2010 International Conference on Computer Application and System Modeling (ICCASM 2010)

A Design of the Intelligent Electronic Control Seat Belt Retractor Based On Automotive Active Safety Technology

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***Abstract*—Designs an Intelligent electronic control seat belt retractor, witch integrated controller area network (Controller Area Network, CAN) communications, millimeter-wave radar technology, micro electro-mechanical systems (MEMS) sensor technology and embedded processing technology. The millimeter-wave radar warning signal, MEMS accelerometer information, occupants status and CAN bus data, trigger the appropriate seat belt traction control strategy, implementation of reminder, collision avoidance, thus it can protect the automotive occupants safe, and reduce or prevent occupants not to be injured during a crash. Therefore, the intelligent electronic control seat belt retractor links up active safety and passive safety technology.**

Keywords-active safety technologies; retractor; CAN bus; millimeter-wave radar; MEMS accelerometer

I. INTRODUCTION

With the rapid development of the automotive industry, related technical research and development has also been a great deal of attention, especially in recent years security concern technologies and equipment attract more attention. How to reduce car traffic accidents, especially to reduce road accident deaths is the world's automotive industry important subject. Vehicle safety technology generally can be divided into active safety technology and passive safety technology. Active safety technology refers to the prevention of pre-installed, avoid accidents of technology; passive safety technology is the methods during the incident occurred or after the accident, to minimize damage. The design of the active control of the seat belt retractor links up active and passive safety technology, provide early warning of a life concern in safety technology, mainly for motorists in the alarming seat belt adjustment, driving and vehicle fatal collision quickly tighten, thus save the occupant life. This article describes the active control of the seat belt retractor is precisely in this context of a cohesive active safety and passive safety of a life concern vehicle safety technology, as in [1].

II. SYSTEM DESIGNS

A. Technical background

This design incorporates CAN bus communication technology, MEMS accelerometer technology, millimeter wave radar technology, embedded processor technology and other advanced communication, testing and data processing technology. The design can receive car status information and various sensors data, through CAN bus and vehicle body control systems, and also sends control messages to the CAN bus. The system uses the MEMS accelerometer and millimeter-wave radar, to get the vehicle deceleration or collision status information, intelligent electronic control seat belt retractor provides seat belt control strategy, as in [2].

CAN (Controller Area Network) bus is a serial data communication protocol which was developed by German company BOSCH in the 1980s to solve data exchange among numerous control and test equipments in modern vehicles. CAN bus has been widely used in electric vehicle control system, due to its advantages such as good real-time feature, high reliability, quick communications rate, simple structure, good interoperability, perfect error handling mechanism of bus protocol, high flexibility, low price and so on, as in [3].

Based on message model, system performance analysis is mainly concerned to calculate message response time and bus load. The worst-case message response time of a queued message, measured from the arrival of the message request to its complete transmission. And bus load is the total message transfer time in per time unit. The message stream set schedule is guaranteed if every message has a response time smaller than its deadline.

1） Response time (R_m) analysis

$$R_m=t_m+C_m \quad (1)$$

The term t_m represents the worst-case queuing delay longest time interval between the arrival of the message request and the start of its transmission.

$$t_m = B_m + \left(\sum_{\forall j \in hp(m)} \left\lceil \frac{t_m + t_{bit}}{T_j} \right\rceil \times C_j \right) \quad (2)$$

Where B_m is the worst-case blocking factor, which is equal to the longest duration of a lower priority message.

$$B_m = \max_{\forall k \in lp(m)} \{0, C_k\} \quad (3)$$

lp(m) is the set of message streams with lower-priority than message stream S_i; *hp(m)* is the set of message streams with higher-priority than message streams S_i; t_{bit} is the duration of a bit transmission, as in [4].

2) Network load analysis

$$U = \left(\sum_{\forall m} \frac{C_m}{T_m} \right) \quad (4)$$

MEMS Sensor technology, capacitive MEMS accelerometer is made of silicon wafer surface of elastic structure of quality block as capacitance in plates, side plates fixed, this will constitute the two threaded capacitor, when acceleration caused mass of location change, changes in capacitance. Use Exchange capacitor technology to measure two capacitance values, and output and acceleration is directly proportional to the relationship between voltage value, as in [5].

The device consists of two surface micromachined capacitive sensing cells (g-cell) and a signal conditioning ASIC contained in a single integrated circuit package. The sensing elements are sealed hermetically at the wafer level using a bulk micromachined cap wafer.

The g-cell is a mechanical structure formed from semiconductor materials (polysilicon) using semiconductor processes (masking and etching). It can be modeled as a set of beams attached to a movable central mass that move between fixed beams. The movable beams can be deflected from their rest position by subjecting the system to an acceleration.

As the beams attached to the central mass move, the distance from them to the fixed beams on one side will increase by the same amount that the distance to the fixed beams on the other side decreases. The change in distance is a measure of acceleration.

The g-cell beams form two back-to-back capacitors. As the center beam moves with acceleration, the distance between the beams changes and each capacitor's value will change.

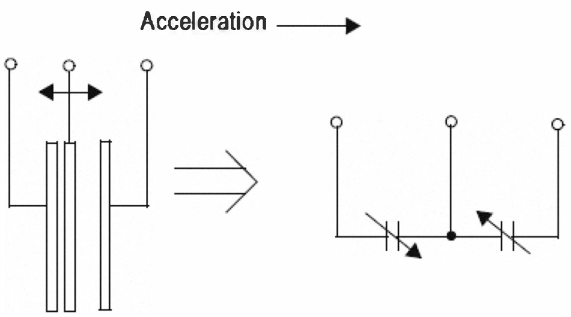

Figure 1. Simplified Transducer Physical Model

$$C = \frac{A\varepsilon}{D} \quad (5)$$

Where A is the area of the beam, ε is the dielectric constant, and D is the distance between the beams, as in [6].

Millimeter-wave radar technology has a high resolution, small, cluttered and multipath effects ability, and penetrates rain, fog, smoke, and a series of advantages, which are widely used in automotive pre-crash systems and intelligent cruise control system.

Millimeter-wave radar is advantageous over laser radar or the like radar that uses an optical source, in that it is reliable even in inclement weather or dusty conditions. However, millimeter-wave radar faced a challenge in that improvement of its object-recognition performance results in a larger and more complex structure. Recently, we have successfully developed an electronically scanned millimeter-wave radar that employs a phased array antenna, and have succeeded in commercializing a millimeter-wave radar sensor which is physically compact and yet superior in object-recognition performance, as in [7].

B. System components

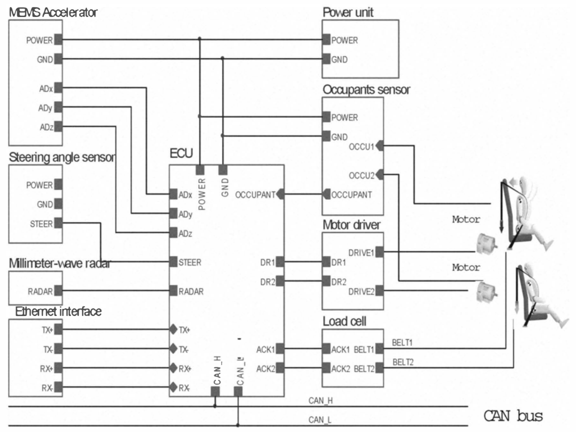

Figure 2. Electronic seat belt retractor control system schematics

This intelligent electronic control seat belt retractor (Figure 2) mainly consists of the following components, MEMS accelerometer, steering angle sensor, millimeter-wave radar, occupant detection sensors, seat belt load cell feedback sensor, ECU(electronic control units), motor driver and stepping motors. The following are the system components' briefly introduction.

MEMS Accelerometer is used to detect the vehicle's acceleration deceleration and overturning. When an accident occurs, the system needs to be set to the corresponding control strategy of seat belt to perform an action. As vehicles fast deceleration or acceleration, deceleration of abnormal or rollover, the ECU will as appropriate to tighten the belt to protect occupant safety, as in [8].

The steering angle sensor is used to detect the wheel's rotation angle and rotation rate, and according to the above test to determine the status, in turn driving judgment is in emergencies or driver is sleepy or fatigue driving status, witch are provided to ECU for control strategy selection.

Millimeter-wave radar is used to measure the obstacle or the distance between vehicles and vehicle speed, and pursuant to the above two data to judge the warning, the early warning signals sent to the ECU for pre-crash policy, to implement active security, as in [9].

Occupant detection sensor is on the seat, by detecting body weight and the distribution of the occupant's weight in the seat, to determine the presence of the passenger and crew of natural conditions state and sitting position, which in turn facilitate the ECU, to select the appropriate seat belts control strategy.

Seat belt load cell feedback sensors test the harness force and thus receive the occupants, and send the signal back to the ECU to determine the occupant comfort and security protection level, to control the motor for seat belt relaxation of adjustment, allowing occupant comfort and security to achieve better coordination.

ECU, as the core section of the control systems, the ECU with an integrated ARM7TDMI-S kernel LPC2290 . As the processor is used for the sensor signal collection and processing, through the CAN bus controller interface chip this system will connect to the vehicle body CAN bus, enable the system and vehicle body control system communication between the sensor to exchange and share control information. According to the information and body state that obtained by sensing to select the appropriate control strategies to control the seat belt perform reminder, early-warning and rapid action to tighten.

Motor drives and stepping motors receive control signals from ECU, and act according to ECU command to implement the seat belt tightening or loosening action. Motor axle by reduction gear and belt hinge attached, to get a reasonable speed, seat belts at the right speed and achieves the objective of pre-tightening, as in [10].

ECU receives configuration information through Ethernet controller interface, as well as downloads the initial set of control strategies. from the host computer.

III. System Control Flow

In this design, the control software runs on embedded real-time operating system, control software complete the sensor data acquisition and processing, CAN Bus communication as well as implementing agencies driven and control function. It is also used to implement traffic status, collision occurrence, and occupants detection, and pursuant to the detected information, combined with an embedded control policy to implement on the seat belt retractor motor control, complete with seat traction, the control flow shown in Figure 3.

System initialization, the ECU into CAN Bus data and traction control strategy, acquisition and occupant detection sensor data information, including the presence of the passenger's weight and seat position information, and so on, and then use this information to target different crew selects the appropriate seat belt traction control strategy. While vehicles are in motion, the ECU under such as millimeter wave radar, MEMS accelerometer, steering wheel angle sensor, and seat belt feedback sensor data information, various data elements, as the parameters in the control strategy, comprehensive implementation on seat belts and control in order to achieve the comfort, security and alarm and security purposes, as in [11].

The following combination of active control seat belt retractor control program flow chart briefly describes each control factor corresponding control policies in actual control, ECU will be based on various factors of the seatbelt weighted to implement traction control strategy of comprehensive.

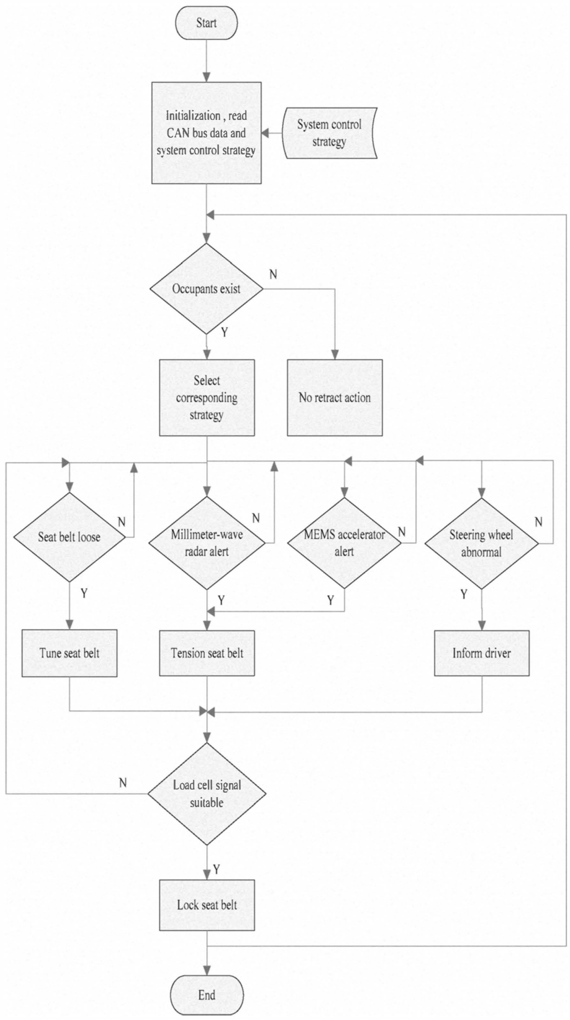

Figure 3. Active control seat belt retractor control program flow

The ECU via steering wheel angle sensor for the rotation of the steering wheel, controlled pre-programmed control algorithm, to determine whether the driving is a State of fatigue driving, when judging the driver is in a State of fatigue driving, the ECU will repeatedly through the control of seat belts, trace and to remind drivers of the purpose of safeguarding security, prevent an accident driving.

The ECU through the millimeter-wave radar detects a collision alarm signal, or detected MEMS accelerometers measure acceleration value changes or exceptions that occur in emergency braking, collision or vehicles overturning, ECU control motor drive quickly tighten the belt, the seat occupant la back and locking seat occupant protection. In the seat belt retractor, the ECU also detects feedback sensor load cell signal of seat belts in order to make the seat belt lock in the appropriate location.

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