Optimal Control System of Automatic Navigation Aircraft Cluster for Mechanical Carrier Vehicles

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Abstract: The fundamental difference among Steer by wire and other steering systems lies in that it cancelled the mechanical or hydraulic connecting device between the steering wheel and the turning wheel, thus it breaks through fixed transmission ratio limit of the meshing gear, and reduces the total clearance among the inertial, friction and transmission parts of the system, and finally improves the response speed and response accuracy of the system. Domestic research mainly focuses on algorithms related to Steer-by-Wire system, such as the algorithms of return torque and stability of the steering wheel. Domestic research doesn't form in-depth research of the communication protocol used in the system. And, FlexRay is through accurate and high speed communication network protocol to meet the requirements of SBW system when there are fault tolerance and time uncertainty of the message transmission, thus to improve the controllability, stability and safety of car handling. Therefore, the research of the SBW system's communication network is a research in a new field, and it is also crucial to improve the vehicle performance and gradually makes it more intelligent.

1. Simulation and performance Comparison of the Software

Assume that there are four nodes in a FlexRay network, and three of which are synchronized nodes. The cold boot process should be ignored while conduct the software simulation process. Besides, we should focus on the clock synchronization conditions of Cycle8~Cycle13--these six cycles, and each cycle should be simplified as ST segment and NIT segment. We should set the relevant protocol parameters meet the following equations gdCycle=1000, gdMacrotick= 1 μ s, pMacroPerCycle=1000, gdStaticSlot=100MT.

In order to calculate the phase and frequency correction value of each node, we should write the FTM algorithm Matlab as: [offsetcorrection, ratecorrection]=FTM_algorithm (num, offsetarray, ownoffset). In the above equation, num is the number of synchronization nodes, for cSyncNodeMax=15, the maximum value of num of is 15; offset- array is the expected arrival time of certain synchronization frame, and it takes the node's local time as reference. Through FTM_algorithm function, we could obtain phase and frequency correction value of each node among Cycle10~Cycle11 as shown in table 1. In table 1, pdMicrotick is the length value of μT, and its unit is μs; and we take μT as unit of phase and frequency correction value.

Table 1 Phase and frequency correction value among Cycle10~Cycle11

nodes	*pdMicrotick*(μs)	Phase correction value(μT)	Frequency correction value(μT)
Non synchronous node	0.1	-820	-43
synchronization node 1	0.025	429	28
synchronization node 2	0.025	-29	-3
synchronization node 3	0.025	-406	-27

2. The Real-time and Fault Tolerance Evaluation of Steering System of Flexray Wire

2.1 The FlexRay communication module hardware

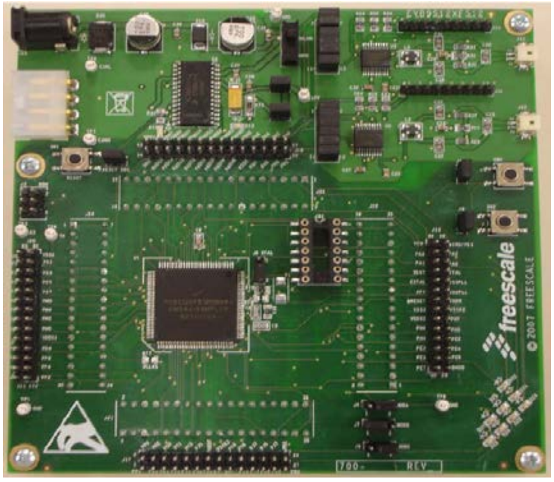

Fig. 1. EVB9S12XF512 evaluation board

In this paper, we choose the EVB9S12XF512 evaluation board of Freescale as basic ECU nodes, as shown in Figure1. EVB9S12XF512 includes a 16-bit-microcontroller: MC9S12XF512 with FlexRay communication controller embedded in it, two FlexRay bus drivers: TJA1080 and a high speed CAN bus driver: MC33742.

(1) Micro controller MC9S12XF512

There is a XGATE co processor, 512K byte Flash and an embedded FlexRay communication controller in the micro controller MC9S12XF512. The package diagram of this micro controller is as shown in figure 2. In figure 2, XGATE is aimed to conduct fast interruption processing, thus it could reduce the load of CPU while conduct interrupt processing. Therefore, it provides a higher level of disruption, and through the sharing of some service procedures it could shorten the working time and process of CPU. XGATE, like CPU, is a programmable kernel that supports the C compiler. When the source is off, XGATE begins to run; when the interruption task is completed, it will stop all the clocks and wait for the next event, thus it could reduce power consumption. Therefore, although MC9S12XF512 is a 16 bit microcontroller, it can achieve the performance that of 32-bit microcontroller.

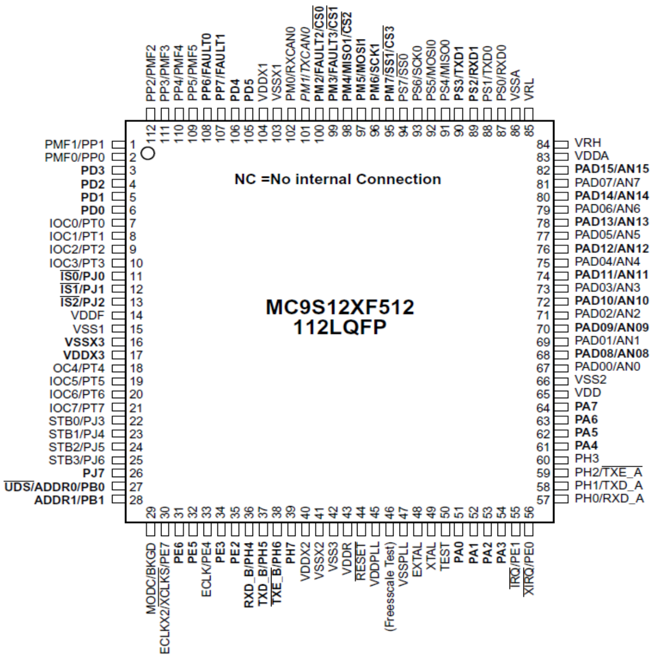

Fig. 2. The package diagram of the microcontroller MC9S12XF512

(2) The FlexRay bus driver

The FlexRay bus driver uses TJA1080 produced by NXP company, and it could provide data rate up to 10 Mbps. So it is suitable for working during the 14V~42V voltage range. And the electromagnetic radiation of FlexRay bus driver is low, and the input differential mode is adopted in this bus driver. The IO terminal voltage of the bus driver can altered by itself accordingly, at the same time, there is BGE interface reserved for the bus monitor. The chip provides 4 kinds of bus states: low power state, idle state, data 1 state and data 0 state.

In order to achieve the voltage adaptive adjustment of the IO terminal, in the circuit, we connect drive voltage of the communication controller (namely the drive voltage of the microcontroller with the VIO pin of TJA1080. And then, no voltage conversion chip is needed to achieve the normal communication between TJA1080 and controller. The bus driver circuit that the channel B corresponds is similar to Figure 3, thus we left out this part.

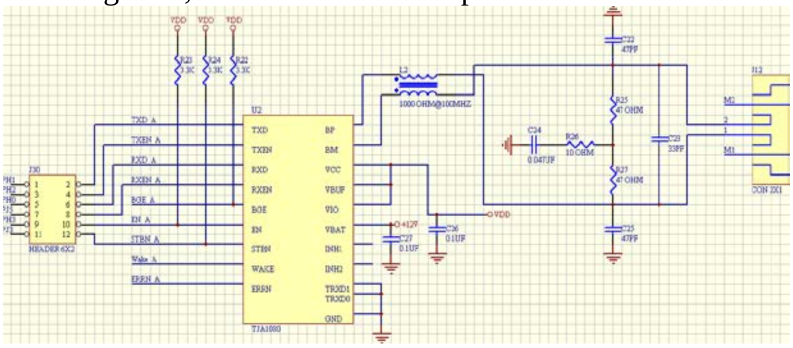

Fig.3. FlexRay bus driver circuit diagram

2.2 Real Time and Fault Tolerance Evaluation

We integrate the steering, yaw warning and electronic stability control system to get the message scheduling scheme shown in table 2-3. The ST segment transmits a ST message containing a variable steering drive ratio and a steering wheel torque, and at the same time it starts and synchronizes this message. Due to the fact that the message in DYN segment is triggered by the event, so when the sensors are in normal state, this segment only receives yaw warning and information related to steering in electronic stability control system; if a sensor failure happens, the correct variable steering transmission ratio or steering wheel aligning torque value will be sent in the previous dynamic slots (here the "correct" value could be obtained from the sending node based on the processing of the previous fault-tolerant calculation. Because that this aspect has nothing to do with FlexRay communication, not many researches are conducted) to correct the error value sent by ST segment in the cycle. In order to ensure the real-time performance of the system, in each cycle we should pre-use the fault-tolerance algorithm to calculate the variable steering drive ratio / steering wheel torque value as backup-information, when there is a fault in the sensor, the ST segment could directly send this value.

Table 2 Priority solution of DYN message (unit:MS)

n	*j*	*Mdl*m	*R*tm	*diff*m
DM1	2	355.5	118.5	237
DM2		361.5	120.5	241

$diff_{\mathrm{Dm2}} \geq diff_{\mathrm{Dm1}}$ indicates that the worst-case response time of DM1 is close to the deadline. In order to guarantee the schedulability of the system, we should first send DM1, and assign the smaller frame ID value to FrameIDDM1. Thus we can get the time slot arrangement in table 3, namely the corresponding dynamic DM1 timeslot 1 (namely slot67), and the corresponding dynamic DM2 2 time slot (namely slot68). And then we receive information related to steering of the yaw warning and electronic stability control systems in the dynamic slot 3 and slot 4 (i.e. slot69, slot70). Due to the fact that the message sending timing is associated with the scheduling of the node, and the two nodes belong not to wire-control steering network, so we don't compare the arrangement orders while receiving time slots.

Table 3 Time triggered schedule

Time slot	MB delivery	MB receive	FIFO receive
STsegment			
slot1	n1,chAB,SM1(start and synchronous frame, and the load data is the variable steering ratio)	n2,chAB	
slot4	n2,chAB,SM2(start and synchronous frame, and the load data is the steering wheel torque)	n1,chAB	
DYN segment			
slot67	n1,chA,DM1(the adjusted variable steering ratio)		n2,chA
slot68	n2,chA,DM2(the adjusted steering wheel torque)		n1,chA
slot69	n3,chA,DM3(information of yaw warning system)		n1 & n2,chA
slot70	n4,chA,DM4(information of electronic stability control system)		n1 & n2,chA

In table 3, the message sending of ST segment is achieved according to the schedule table, while DYN segment obtains the present message scheduling by dynamic programming algorithm. Therefore, we can adjust the arrangement according to actual condition. In this table, SM stands for the Static message, namely ST message; The abbreviation of Dynamic message is DM, namely DYN message; chAB means sending or receiving data with double channels, and chA means sending or receiving data only with channel A; n3 and n4 are respectively the nodes in yaw warning system and electronic stability control system. Due to the fact that the microcontroller MC9S12XF512 does not support the dual channel communication of DYN segment, so we only use channel A to send and receive message.

3. Conclusion

In the aspect of clock synchronization, we introduce the concept of phase deviation state diagram. We replace the real time intervals with continuous time intervals, and based on the more accurate clock discrepancy information to improve the network synchronization accuracy; and according to the weight changes of the state diagram, and conduct real-time and dynamic evaluation of the synchronization clock performance of the synchronization nodes and the stability of the network to make each node's local time be closer to the global time.

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