

# Design and Implementation of Digital Signal Processing Module Based on PCI Bus and FPGA

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**Abstract.** Signal acquisition and processing technology based on FPGA is researched. FPGA is the core of the signal acquisition and processing systems, it controlled each module to complete signal acquisition and processing tasks. The article mainly researched and designed of FPGA-based control and processing systems, including FPGA-based signal acquisition module, FPGA-based signal processing module and FPGA-based storage control module. Acquisition and control module is mainly for controlling channel selection switch and A / D converter to work that generate multi-channel selection logic control signals and A / D conversion timing control in order to complete the multi-channel analog input signal acquisition control; Signal Processing Module mainly for through the A / D converted digital signal to FFT processing; storage control module's role is to control the memory work, that is, memory logic control signals generated, in order to achieve control of the processing results of store.

## Introduction

Real-time scheduling theory was very critical research in real-time control systems. The bus-based robot control systems[1] should connected all functional components to a unified bus, it achieved a high degree of loosely coupled structure[2]. However, due to the intervention of the bus, the components should not directly interact each other, it caused a delay and packet lossing, and affected the performance of the control system eventually. So,it was necessary to adopt the method of scheduling and control co-design[3], we should consider the scheduling problems of messages on the bus while designing the control system, that should improve the real-time and achieve performance optimization of the systems.

In the research on the scheduling for the messages on the bus, a hybrid scheduling model for the FlexRay bus had been proposed [4], in this paper, messages has the Static Segment (SS) and Dynamic Segment (DS), researchers used an extended SAE benchmark for the FlexRay network to identify the static and dynamic tasks, and calculate the response time,then the deadline of the tasks was insured. In the paper[5], a bi-objective model had been proposed to deal with production scheduling and maintenance planning problems and the solution of the integrated model is based on multi-objective ant colony optimization approach. An improved dynamic EDF scheduling algorithm was proposed for the Network control systems in the paper, the scheduling strategy is to change task priority according to the transmission error over deadline task when applying dynamic EDF scheduling strategy.

In this paper, we studied the theories of the bi-objective model、dynamic EDF scheduling algorithm and the feedback scheduling, aimed to the architecture of the robotic control system in this paper, we designed the two level scheduling scheme which involved the task scheduling on the bus and scheduling optimization for the bus resource. The first level scheduling, Considering the effects of transmission errors and response times, we proposed the “based on improved fuzzy feedback EDF scheduling policy”, the basic idea of this strategy as follows: the first, assigned task priority based on improved EDF scheduling algorithm when the messages arriving the bus, then, adjusted the priority of each task according to the feedback information (the weighted of the transmission errors and response times) when the scheduler’s sampling period on arrival; The

second level scheduling, adjusted each task period according to the feedback information, reallocated the bus resources, ultimately, we achieved the suppression of the deterioration of the system performance.

## Scheduling module

The number of control loops and application nodes which effected on the bus resources and CPU resources was time-variant in these control systems, the loads which was uncertain or unknown led to the unexpected runtime environments. In the uncertain environment, the control methods based on the offline designing in the predictable environment would lead to the deterioration and instability of the system's performance, we need deal effectively with the influence on the performance because of the uncertain resources, and provide support for the performance optimization in dynamic environment (uncertain loads) .

So, we proposed the feedback scheduling policy. The scheme included the features as follows: it took the multi-objective function which composed of the packet loss rate and response time as a measurement standard, assigned priority of each tasks using the method of the “based on improved fuzzy feedback EDF scheduling policy”, then achieved the suppression of the deterioration of the performance. Other, we allocated optimally the bus resources through the feedback messages, adjusted the sampling period of each tasks, and further optimized the system performance.

The scheduler(Figure 1) involved the scheduling policy on the bus layer and application layer. The priority configurator set the priority of all the task's messages and put the messages into the ready task queue. The bus resource manager adjusted the task's period to reallocate the bus resources, then increased the bus utilization and meet the real-time requirements of control systems.

In a sampling period of the scheduler, the feedback performance index function,  $J_f(j) = \alpha E(j) + \beta \tau(j)$ ,  $E(\text{packet loss error rate}) = [X(j) - X_s(j)] / X(j)$ ,  $X(j)$  represented the total number of data packets,  $X_s(j)$  represented the total number of the data packets which had been transmitted successfully,  $\tau$  (response time ratio)  $= H(j) / H_{\max}$ ,  $H(j)$  was the execution time of the task,  $H_{\max}$  was the task's maximum execution time,  $\alpha$  was the weights of the packet loss rate,  $\beta$  was the weights of response time ratio, and  $\alpha + \beta = 1$ ; The differential of performance indexes  $J_{Cf}(j) = J_f(j) - J_f(j-1)$ , it echoed the direction of change for performance indexes. The performance index function could be transformed into a single objective optimization problem using the weight sum method. Weights need to be based on the actual system requirements or determined by the simulation method, if the response time was ample then the weight of error should be increased, if the response time was running out, their weights increased.

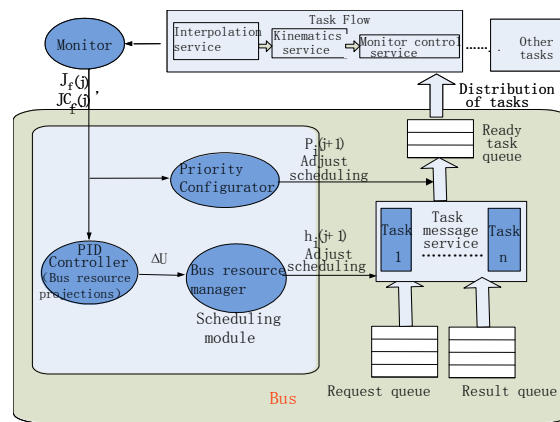


Figure 1 Feedback control scheduling framework

If there were  $n$  tasks running in the control system, the sampling period of the scheduler  $h_f$  should be equal to Integral times of the period of the longest task.  $h_f = A_{\max}[h_i]$ ,  $A$  was an integer,  $h_i$  was the period of the  $i$ -th task,  $i \in [0, n]$ , in order to avoid frequent switch of scheduler

affecting the performance of the system,  $A$  greater than 1 generally. Assuming that  $h_i$  was the longest period of the task, there were three tasks: interpolation task, kinematics task, and motion control service, the period of all the tasks was  $h_i$ , taking into account the integrity of the process,  $A$  took the value of 3, then  $h_f=3h_i$  (Figure 2).

The scheduler was time driven, it monitored the operational status of each task when sampling time coming, and obtained the following informations:

The numbers of packets that had been send to the bus by each task  $X(j)$ , and the packets that had been transmitted successfully by the bus  $X_s(j)$ ;

The task's command response time  $\tau$  and the forwarding times of the tasks on the bus  $\tau_b$ .

In this paper, the bus utilization and the task's priority had been allocated dynamically according to the feedback performance of the task loops, if the performance of the control task loops was worse, then the task should be assigned to more bus resources and the higher priority. The task scheduling policy and the bus resource scheduling described as follows.

### Packet loss ratio testing

Test Environment: the deadline of the packets was 20ms, there was a testing process for interference. Set  $K_P=5$ ,  $K_I=10$ .

The data of the packet loss rate testing without the scheduler shown in Figure 3. Its packet loss rate was 3.69.

The data of the packet loss rate testing with the first level scheduling shown in figure 4. In this experiment, we used the first level scheduling what was task's scheduling, and the second level scheduling what was the bus resource scheduling had not been considered. The packet loss rate was 0.85%, it was significantly lower than the values without the scheduler. The experiment proved that the first level scheduling could effectively reduce the packet loss of the system.

The data of the performance testing with two level scheduling were shown in Table 1.

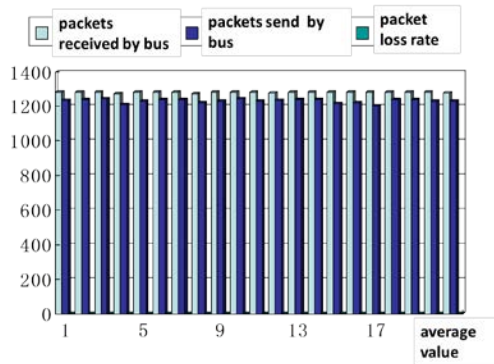


Figure 2 Packet loss rate testing without the scheduler

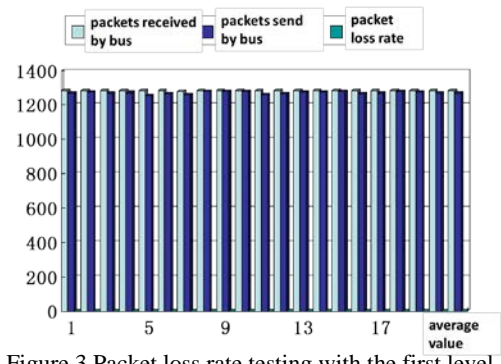


Figure 3 Packet loss rate testing with the first level scheduling

Experimentally measured that the packet loss rate was zero when the system used two levels scheduling module, and the resource utilization of the bus arrived to 100%. The experiment proved that the two levels scheduler not only ensured the lower packet loss rate, but also effectively improved the utilization of the bus.

Table 1 The performance testing with two level scheduling

	Packets send by bus	Packets received by bus	Packet loss rate	Utilization of bus
1	1241	1241	0	1.0
2	1240	1240	0	1.0
3	1234	1234	0	1.0
4	1328	1328	0	1.0
5	1222	1222	0	1.0
6	1132	1132	0	1.0
7	1342	1342	0	1.0
8	1234	1234	0	1.0
9	1342	1342	0	1.0
10	1321	1321	0	1.0
Average values	241	241	0	1.0

## Conclusion

The two levels scheduling framework in this paper applied to the control system based on bus. First, we used “the improved fuzzy feedback EDF scheduling policy” to adjust dynamically the priority of the tasks according to the task’s deadline, the importance and the feedback of performance index. Then , the packets with greater importance should have the higher priority to be transmitted, the packets closer to the hardware should have the higher priority too, the priority should be increased when the performance of the control loops was worsening, and achieved the suppression of the deterioration of the system performance. Secondly, we adjusted the sampling period using the bus resource scheduling policy, controlled dynamically the traffic of the messages on the bus. that ensured the schedulability on the bus ,reduced packet loss and delay, and got better performance than the system with fixed sampling period. Finally, the experiment results shown that the scheduler could effectively solve the problem of slow response and packet loss what were caused by the introduction of the bus .

## References

- [1] Esquivel-Flores O, Benítez-Pérez H, Méndez-Monroy P, Ortega-Arjona J. Bounded communication between nodes of a networked control system as a strategy of scheduling. *International Journal of Parallel, Emergent and Distributed Systems*, December 2012, p 481-502.
- [2] Zhu Xiuming ,Huang PeiChi,Han Song,Mok Aloysius K,Chen Deji,Nixon Mark. MinMax: A sampling interval control algorithm for process control systems. 18th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, RTCSA 2012 - 2nd Workshop on Cyber-Physical Systems, Networks, and Applications, CPSNA, 2012,p 68-77.
- [3] Y. Geng, J. Chen, K. Pahlavan, Motion detection using RF signals for the first responder in emergency operations: A PHASER project[C], 2013 IEEE 24th International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), London,Britain Sep. 2013
- [4] S. Li, Y. Geng, J. He, K. Pahlavan,Analysis of Three-dimensional Maximum Likelihood Algorithm for Capsule Endoscopy Localization, 2012 5th International Conference on Biomedical Engineering and Informatics (BMEI), Chongqing, China Oct. 2012 (page 721-725)
- [5] Y. Geng, J. He, K. Pahlavan, Modeling the Effect of Human Body on TOA Based Indoor Human Tracking[J], *International Journal of Wireless Information Networks* 20(4), 306-317