Hardware Implementation of a High-performance Programmable Digital Processing System for Radar Proximity Fuze

Di Wu, Zhang'e Ma, Xiutan Wang, *Hainan Diao
Department of Electronic Engineering, Tsinghua University,
Beijing, 100084, China
* Luoyang Optic and Electronic Center
Luoyang, 471009, China

Abstract --- A new type of digital processing system for radar proximity fuze is described in this paper. By utilizing High-speed Real-time digital signal processing devices and special FFT processor, a High-performance system has been developed which allows for the digital signal processing purpose of radio proximity fuze. Reasonable overall architecture and programmable processors using in this system notably improve its programmability and scalability. This system is a successful embodiment of the latest designing ideas of digital receiver and software radar.

I. Ntroduction

Guided weapon systems require a proximity fuze[1] device to trigger the explosive warhead. Because of the close fuzing ranges and the high relative velocity between the missile and the target, the signal processing system of the proximity fuze must have fast processing ability and reasonable system architecture. To meet this requirement, we present a new type of Frequency-domain Digital Signal Processing System (FDSPS) in this paper. Based on MTD [1]~[3] technique, FDSPS is capable of digitally processing near-field radar echo in frequency-domain.

Figure 1 shows the detailed processing flow of the FDSPS. Compared with the time-domain based radar proximity fuze[4], the FDSPS employs high-speed A/D, FFT and Pythagoras Processors[5], transforms the radar signal into Frequency-domain. In this case, the azimuth resolution and velocity resolution is increased. Further more, it can perform some advanced functions such as missdistance indicate、interference type and target identification[2]. By utilizing programmable devices for digital signal processing, the FDSPS has good commonality、reproducibility and programmability. It is applicable for various types of the radar proximity fuzes and is a successful embodiment of the latest designing ideas of digital receiver and software radar[6].

II. Real-time Property

Radar proximity fuze is different from other general-purpose radar system. The most significant feature is the short computation time in target detection and moving target information extraction. For missile fuzing applications, the transmitting and receiving antennas on a missile are generally located in the near-field zone of the scattered field. In consequence, the radar return computation is complicated and time-consuming. On the other hand, the available time for signal processing is very short. When the missile encounters the target face to face, the relative velocity is as high as 8 Mach. In order to effect correct operation to the warhead of the missile, the signal processing system must produce the correct output within the correct time interval. Generally, the whole processing loop is required to complete within several ms[1].

In the following, we present the architecture and the processing flow of the FDSPS. These descriptions provide supporting detail to the real-time property of the FDSPS. The system parameters are defined as follows: T_{sp} denotes the scan period of radar proximity fuze, M denotes the sampling points in one scan period, N denotes FFT points. According to the operation mode of the radar proximity fuze (i.e. multi-quadrant scan and detection), the FDSPS is designed to accumulate the sampling data at the same quadrant in different scan period. In the period of NT_{sp}, the FDSPS will gain M groups of data, each contains N sampling points.

As shown in Figure 1, these data will pass through four modules: pre-processing module, FFT module, intermediate module, reprocessing module. We now consider the processing time of each module.

The base-band signal firstly was input to the pre-processing module in which it was latched, selected and rearranged. Then, it was written into the dual-port static RAMI. The RAMI is working in PING-PANG mode. That is, when MN points of data was written into the PING part, the same number of previous data in PANG part will be read by the FFT module at the same time. This implies that the processing time of pre-processing module (i.e. the PING-PANG switching time of RAMI) is equal to NT_{sp}. To ensure MN points of data can be processed without any loss, the RAMII and the re-processing module must process them at the same rate. This is important for the real-time applications. In this way, the total processing time of these three parts will be 3 NT_{sp}. Generally, the scan period of radar proximity fuze will be several μs. However, the intermediate-processing module is driven by system clock which is 40MHz. Compared with the T_{sp}, data processing time in this module such as data latch,

0-7803-7000-7/01/$10.00©2001 IEEE.

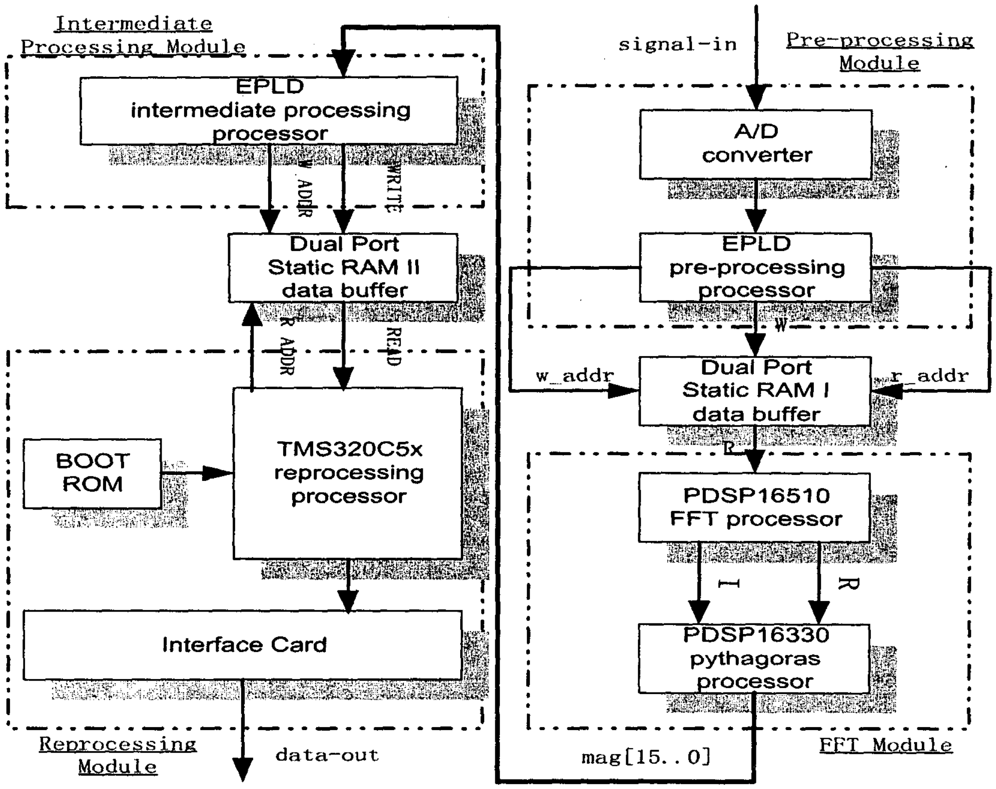

Figure 1. Processing Flow of the FDSPS

truncation and CFAR time will be ignored.

In the following, we analyze the processing time of FFT module. This module consists of two special FFT devices: PDSP16510 and PDSP16330[5]. The PDSP16510 performs Fast Fourier Transforms on complex or real data sets containing up to 1024 points. An internal RAM is provided which removes the memory transfer bottleneck. In the continuous mode, with transform sizes of 256 points or less, it contains three internal control units which simultaneously allow new data to be loaded, present data to be transformed, and previous results to be dumped. Additional external input/output buffering is not needed.

The PDSP16510 is driven by the system clock that is 40MHz. In a single device system, if $N=256$, the transform will be completed within 816 clock periods[5] (i.e. 20.4μs). When 256 point transforms are

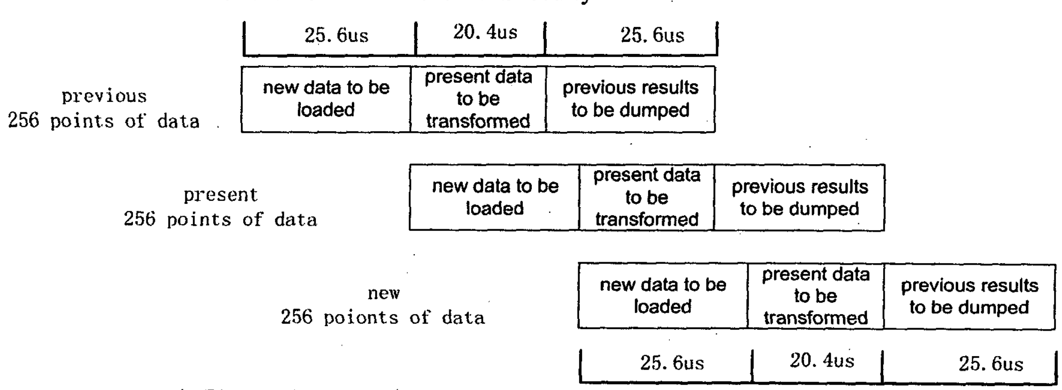

Figure 2. Continuous operation mode of PDSP16510

calculated, without loss of incoming data during the transform time, it is necessary to choose the input/output clock at 10MHz. Hence, the input/output time of 256 points will be 25.6μs.

Figure 2 shows the continuous operation mode of PDSP16510. In this mode, the PDSP16510 can simultaneously input new date, transform date stored in the RAM, and to output previous results. The 256 points of data then can be transformed to the frequency-domain within 80μs. The less length of the transform size, the short transform time is. Due to the near-field[1] working environment of the radar proximity fuze, the FFT scale larger than 256 points will not be available. So the transform time is less than 80μs.

Referring to the analyzing above, the overall processing time will shorter than 3 NT_{sp} + 80μs. Generally, the T_{sp} is several μs, N <256, so the overall processing time will be several ms.

III. Programmability of the FDSPS

Figure 3 shows the programmability of the FDSPS. The two dual-port static RAM function as the data buffers that divide the whole system into three independent parts. This enhances its commonality and reproducibility. By utilizing the programmable devices, the programmability of the FDSPS is also increased. Some technical parameters can be modified easily without changing the hardware architecture. Based on the FDSPS, the development time to implement new models and products of radar proximity fuze will be cut down.

Pre-processing module and intermediate processing module use technical grade PLD devices to perform their functions. The PLDs can offer following advantages (e.g. higher performance, high-density logic integration, greater cost-effectiveness, shorter development cycles with MAX+PLUSII software, shorter development cycles with mega-functions) based on innovative architectures, advanced process technologies, state-of-art development tools.

In the FFT module, we employ PDSP16510 to transform data into frequency-domain. The PDSP16510 is a configurable device. Its operating mode is determined by the condition of 16bits Internal Control Resister (ICR). In the system initial period, we can configure the ICR by means of the programmable interface. According to the actual working situation of the radar proximity fuze, the lower 3bits of the ICR can be modified. As shown in table 1, the PDSP16510 will run in the different FFT scale that notably enhances the practicability of the FDSPS.

Table 1. PDSP16510 FFT Scale Configuration

BITS	Dec'	OPTION
2:0	000	16×16 complex
	001	4×64 complex
	010	256 complex
	011	1024 complex
	100	8×64 real
	101	2×256 real
	110	2×1024 real
	111	Not used

Shown as table 2, the bits 5:4 define the choice of window operator. Either a Hamming or a Blackman-Harris window operator can be internally applied to the incoming real or complex data. The latter gives 67dB side lobe attenuation. The operator values are calculated internally and do not require an external ROM nor do they incur any time penalty.

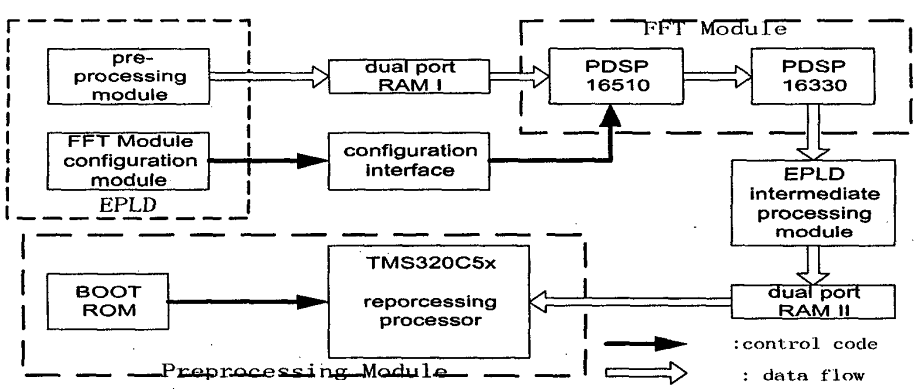

Figure 3. The Programmability of PDSF System

Table 2. PDSP16510 Windows Configuration

BITS	Dec'	OPTION
5:4	00	Rectangular
	01	Hamming window
	10	Blackman-harris
	11	Inverse transform

The central DSP processor in the reprocessing module is TMS32C5x. It notably increases the programmability of this module. As the representation of the new generation of the DSP devices, the TMS320C5x high performance digital signal processors are designed with an advanced Harvard-type architecture (AHARC) [7] that maximizes the processing power by maintaining two separate memory bus structures, program and date, for full-speed execution. Instructions support data transfers between the two spaces.

What we should accentuate here is that the processing period of TMS320C5X (i.e. NT_{sp}) will increase along with the increasing of the FFT scale (i.e. N). However, the processing software of the FDSPS has the linear increase relationship with the FFT scale. Hence, the software can be applied directly when the FFT scale changed. This feature is very helpful for the application of different types of radar proximity fuze.

IV. Conclusion

As real-time application, the FDSPS utilizing hardware to transform the sampling data from time-domain into frequency-domain gains the time for the intermediate processing and reprocessing. This ensures the actual processing period meet the requirement of quick-reaction capability of radar proximity fuze. On the other hand, by employing the programmable devices and dual-port static RAM, the FDSPS provides a flexible hardware platform for the application software.

The FDSPS has been specifically tested as a digital signal processing system in a concrete high performance prototype of radar proximity fuze. It not only has the general functions (e.g. estimating the azimuth, target velocity measuring, radar ranging, anti-interference), but also can perform some advanced functions (e.g. target identification, interference type indication). The FDSPS is a successful embodiment of the latest designing ideas of digital receiver and software radar.

References

[1] Tangwen Liang, Design and Emulation Techniques for the Fuze of Anti-aircraft Missile, Space Navigation Press, 1995.

[2] J.L.Eaves and E.K.Reedy, Principles of Modern Radar, Van Nostrand Reinhold Company, New York, 1987

[3] Hainan Diao, The Digital Filter Design in MTD Technique of Radar Proximity Fuze, Guidance and Fuze, Vol. 21, No.1, Feb. 2000

[4] R.W.Burns, Early history of the proximity fuze(1937～1940), IEE Proceedings,vol.140A, pp224～236,1993

[5] Mitel Semiconductor, supersedes version in December 1993 Digital Video & DSP IC Handbook, May 1996

[6] Zhonghua Huang, Zhanzhong Chui, Research on the software radar proximity fuze, Guidance and Fuze, Vol. 21, No.1, Feb. 2000

[7] Texas Instruments Incorporated, User's Guide TMS320C5X, 1993.