DSP Technology and Its Application in Fuze Signal Processing

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Abstract. The continuous innovation of the embedded digital signal processor (DSP) brings new opportunities for the breakthrough of fuze technology, so that the weapon system can complete the detection battlefield, precise control, high-efficiency damage without changing the existing shape and volume of the fuze. This paper first introduces the advantages and characteristics of DSP chips, then summarizes the application of DSP in a variety of fuze signal processing. Finally, the development direction and application trend of DSP in fuze are prospected.

1. Introduction

The Digital Signal Processor (DSP) is an embedded microprocessor designed for real-time digital signal processing. Its instruction algorithm and system structure are specially designed to quickly implement various digital signals. The processing algorithm has the advantages of small size, simple logic design, fast calculation speed and low power consumption, and is very suitable for embedded real-time processing system. Today, as intelligent devices become more and more popular, DSPs, which are important control processing modules, have not penetrated into various fields, such as medical devices, military communications, automatic control, aerospace, smart home appliances, etc. Their powerful signal processing capabilities have enabled many fields. Traditional technology has found a new direction of development.

With the continuous change of the modern war mode and the constant change of the operational concept, people have changed from the extensive attack mode of pursuing face killing to the precise and efficient destruction of ammunition, which has put forward higher and higher requirements for fuze. The digital signal processing technology provides an effective way to realize the fuze system real-time processing of battlefield signals, realize multi-dimensional cross-linking of combat information, and complete complex algorithms at high speed, which greatly improves the real-time control ability, intelligence degree and stability of the fuze system. In terms of the specific application environment of fuze signal processing, since its main feature is fast and efficient real-time operation, real-time digital processing of fuze signals is the key to its technology. The TMS320 series DSP chip produced by American TI Company has wide application range, strong processing capability, small size and low power consumption. It is one of the embedded processors preferred for digital signal processing. The DSP chip fits well with the work requirements of fuze signal processing, and has received extensive attention and key development at home and abroad.

This paper first introduces the functional characteristics of common DSP chips, and then introduces the requirements for fuzes under the new battlefield conditions, introduces the near-fuzzing fuze, overload detection fuze and ballistic correction fuze which have extremely high requirements in
signal processing, summarizes the DSP in the application status of each of the above fuze signal processing and analyzes the development trend of DSP technology in fuze signal processing.

![Figure 1 TI's DSP Products](image)

At present, the leader in the field of DSP in the world is TI Company of the United States, and its TMS320 series chip is one of the most widely used products.

Compared with the traditional single-chip microcomputer, the internal control system adopts the improved Harvard structure, which changes the inefficient storage and operation mode of the previous program and data mixed storage, stores the program and data in a special independent space, and correspondingly sets the program bus and the data bus. In this way, it greatly improves the program running speed and data throughput. Its instruction system adopts a pipeline structure, which allows its pipeline operation to be overlapped during program execution, reducing the instruction cycle. It has special instructions for digital signal processing, which can quickly and efficiently complete various complex algorithms and realize special functions. Different series of DSPs leave interfaces for multi-machine cascade or parallel connection in structure design, so that it supports multi-machine parallel operation. Due to its special design in structure and instruction, DSP chip has the characteristics of high compilation efficiency and fast instruction execution. It is very suitable for digital filtering, FFT, spectrum analysis, etc. At the same time, DSP chip is small in size, low in power consumption, and core can be programmed. Programming, with high floating-point precision, is ideal for use in space-constrained but highly demanding fuze systems, and is the most commonly used embedded processing for internal signal processing.

2. Application of DSP (Digital Signal Processor) in fuze signal processing

2.1 near-explosive fuze

The near-explosive fuze mainly relies on the characteristics of the target physics to perceive the existence of the target and detect the speed, distance and direction of the relative target, and control the ammunition explosion at the most favorable distance from the target. By installing different types of sensors internally, the proximity fuze can sense various physical field signals. Currently, there are many radio fuzes, optical fuzes, electrostatic fuzes, acoustic fuzes, and magnetic fuzes.

The main principle adopted by radio fuzes is the Doppler effect, which was first applied during the Second World War. The advantages are low cost, small size, simple design, but the disadvantages are also very obvious. The traditional radio fuze relies on the analog quantity output of the analog device to control the detonating circuit, although the anti-interference ability can be improved by designing the filtering circuit and adding the amplitude increasing limitation. However, the influence of the interference signal is still large, resulting in too low precision, large spread of the explosion point, and high premature rate of the fuse. After a long period of research and development, radio fuzes also use digital design detonation control circuits, but early embedded processors could not complete the complex filtering and fast calculation of digital signals, which led to the development of radio fuzes. The emergence and application of DSP has solved the problem of digital signal processing. In the radio fuze, the DSP is used to perform more comprehensive and complex monitoring and analysis of the target signal, such as Kalman filter and Fourier transform, which can greatly improve the anti-interference ability of the system and effectively suppress the fuze malfunction caused by random
interference and human interference; The fast and efficient control system of DSP makes the safe time control and self-destruction time control of the ignition capacitor more accurate and reliable, which simplifies the fuze circuit and improves the reliability of the fuze. By using the DSP to process the radio echo signals, the target recognition capability of the radio fuze system is improved, and the detonation accuracy is improved.

Compared with radio waves, lasers have strong directionality, good monochromaticity, good coherence, and excellent performance. Therefore, laser fuzes have been developed. The development trend of laser fuze is the modularization of its various parts and the software of the whole system, which makes it adaptive, programmable, flexible, intelligent and anti-interference. The fixed distance system of active laser fuze mainly includes triangulation method, distance selection method, pulse phase detection method and pulse laser range finder method, and there are many laser distance fuze algorithms, such as constant ratio timing method and digital. Cross-correlation method, centroid method, and dyadic wavelet method, etc., regardless of which distance and distance algorithm are used, the digital signal processing module needs to have a large amount of data, realize fast digital processing of signals, and operate stably. It is the strength of DSP. Taking the binary wavelet fixed distance algorithm with the best ranging accuracy as an example, DSP's excellent digital signal processing performance can realize real-time signal filtering and echo wavelet transform, and can quickly and accurately calculate the wavelet transform of the echo signal at the singular point. The modulus maxima generated. Through the fast and accurate wavelet transform, the echo signal singular point can be obtained to know the time of the echo wave to the point, and the projectile distance can be obtained by comparing with the initial time of transmitting the pulse signal. The digital signal processing process completed by DSP is not only fast, high precision, and has strong anti-interference ability. The simulation error of the system is ±0.75m, which greatly improves the accuracy of the laser proximity fuze.

In addition to these two fuzes, other proximity fuzes also have high requirements in the digital processing of signals, and the application of DSP is also very extensive. For example, if the acoustic fuze system of the intelligent mine of the neural network is applied, the DSP needs to perform gain and delay processing on the A/D converted digital signal, and judge the trigger condition to control the follow-up system to complete the locking and tracking of the target. At the same time, DSP can also run neural network learning algorithm and recognition algorithm, perform spectral recognition feature extraction of target signal, neural network feature recognition, etc., so that fuze can have learning and memory ability, improve its intelligence and accuracy; The fuze is electrostatically charged by friction during the flight of the air target, external field induction, engine combustion, etc., and the target signal is detected by the corresponding sensor. Since the bullet rendezvous is often only a few hundred or even tens of milliseconds, the high-speed data processing performance of the DSP can be used to obtain the bullet distance in time to achieve the best position detonation.

2.2 Hard target penetration fuze

The hard target penetration fuze is mainly for deep-buried underground or hidden targets in buildings. It requires fuzes to acquire the penetration characteristics in real time during the process of projectile penetration, and then analyze and process the feature quantities. A pre-set optimal detonation point emits a detonation signal for maximum damage. At present, the detonation control methods for deep target penetration fuze to achieve deep damage mainly include timing detonation, meter-counting hole detonation, metering detonation, and target medium identification detonation. Since the detonation control system requires both strong real-time control requirements and many signal processing processes and algorithm design of speed and travel, DSP is often used to complete the signal processing during the penetration process to achieve the best position damage.

In the layer-counting hole detonation method fuze, simple signal low-pass filtering and signal demodulation can be completed by hardware circuits, and then the feature recognition of the acceleration signal needs to be completed by using the DSP algorithm. In fact, due to the complexity of the penetration of the hard layer medium, the penetration process of the projectile is also very
complicated. For example, the hard layer hollow which penetrates the target, the hard layer stack and the other medium in the middle of the hard layer may cause the sensor to output double-peak interference. Continuous signal such as small peaks and continuous double peaks, and due to the programmability of DSP and superior computational processing ability, different conditions can be distinguished by threshold and time setting to distinguish between interference signals and hole signals. The fuze combined with the DSP can not only identify the change of the target layer medium, but also can accurately calculate the number of hard layers and holes passing through the projectile. When the count is equal to the set value, the explosive ammunition is obtained to achieve the adaptive explosion point precision. The purpose of control.

The principle of the penetrating fuze of the trip is to calculate the path of the penetration bomb into the target in real time, so that the projectile detonates at a predetermined distance. The precise calculation of the projectile's penetration stroke requires consideration of complex parameters such as the attitude of the projectile, the penetration speed, and the characteristics of the target medium. The detonation timing of the projectile is determined by its actual penetration state and medium environment, so the real-time processing of the fuze The algorithm is very complicated, so most of them use DSP chips as internal processors. The projectile will be interfered by high-frequency signals such as stress waves during the penetration of the hard target. First, the appropriate filtering method should be selected for preliminary signal processing; then, according to the medium, the shape of the projectile, and the speed and angle of the projectile. The parameters related to the penetration calculation formula are obtained. Finally, the stroke curve of the penetration process can be obtained by the acceleration control data processing by the integral control algorithm.

2.3 Ballistic correction fuze

The ballistic correction fuze refers to a new concept fuze that uses the adjustment device to control the ammunition flight trajectory by comparing the solution ballistics with the actual flight trajectory. It combines the ballistic correction technique with the fuze technology to solve, control and correct the flight trajectory through fuzes, reducing the spread of ammunition. The biggest difference between the ballistic correction fuze and the traditional fuze is that it can detect the actual trajectory of the projectile and compare it with the pre-set nominal trajectory, and correct the flight distance and direction of the projectile with the target information. In order to simultaneously satisfy the miniaturization design of the fuze and the detection and correction of the ballistics, it is necessary to digitize the information control and signal processing of the fuze system, and use advanced digital signal processing technology to achieve real-time, fast and precise control. DSP is a programmable device with fast operation and simple operation language, which satisfies the needs of digital signal processing of ballistic correction fuze.

The development and development of the ballistic correction fuze has gone through three stages. At present, the more advanced and more adopted scheme is a two-dimensional ballistic correction fuze combining high-precision GPS positioning technology and mature magnetoresistive sensor (MR) technology. The GPS/ MR integrated navigation method comprehensively uses GPS navigation information and geomagnetic attitude measurement information, does not depend on meteorological conditions, and is not subject to day and night restrictions, but the amount of data that needs to be solved is large, and the real-time performance is strong, which not only needs to generate the cutting magnetic field. The signal is processed quickly, and at the same time it is necessary to accept GPS navigation information, and once it loses the connection, it will lose control. Selecting the DSP as the core of the information processing unit can quickly and accurately realize the ballistic information setting, GPS information processing, attitude information calculation, ballistic extrapolation processing, ballistic correction function and explosion point precise control function, which can be completed under the condition of satisfying low power consumption. A large number of complex digital filtering and floating point operations such as FFT, through the real-time receiving of the projectile position and the solved attitude data, the resistance adjustment device is opened in time to complete the two-dimensional ballistic correction until the target is accurately hit. In addition to
GPS/MR combination fuzes, DSP also has a wide application space in ballistic correction fuzes using attitude sensors such as solar sensors, inertial devices, and infinite telecom standards. Its powerful digital processing capability can satisfy the ballistic correction fuze system. The baseband information and the received information are quickly solved in real time, and the fuze is adaptive, dexterous and intelligent.

3. Conclusion
In the future battlefield, the fuze as the "brain" of the weapon subsystem has been continuously expanded and extended. However, it is limited by size, size and environmental conditions, so the software development of fuze has become an important development direction. The software of fuze is mainly reflected in the information control and signal processing of fuze. DSP can provide powerful digital signal processing capability for fuze system, combined with advanced sensor technology, satellite positioning technology, target/environment detection technology, information countermeasure technology, modern signal processing technology, and electronic system integrated digital technology to realize the collection of information. Digitization in the time domain or frequency domain to quickly and accurately control the explosion of ammunition for the best damage. Programmable embedded digital signal processor (DSP) promotes the development of fuze technology in the direction of programmable, adaptive and intelligent, so that ammunition has the "eye" of clear battlefield environment and the "brain" of independent thinking. The goal of efficient hitting. In the signal processing of fuzes, digital signal processors will be more widely used.

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