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FPGA - DISRUPTIVE TECHNOLOGIE FOR MILITARY APPLICATIONS

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Abstract: *The paper deals with important topic of nowadays - using FPGA in military applications. The FPGA are used in the defence industry instead of ASIC circuits for the same reason as in the civilian sector currently. The main advantages of the FPGA are presented in the paper. Base on these advantages we can define several military applications of the FPGA. The implementations of these applications are compared with traditional way and benefits of these solutions are presented.*

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1. INTRODUCTION

At present, the armed forces are dependent on technology. The technology is used to ensure domestic security and success in the deployment of troops abroad. To make the armed forces always at least one step ahead of opponents, it is necessary to use the latest technology.

Types of ASIC circuits were previously the dominant choice for military and defence industry, which is not at all surprising. The armed forces have increased requirements for resistance, temperature tolerance and reliability. However, at present FPGA circuits are also beginning to pursue this particular market segment. The FPGA circuits did not represent comparable alternative to ASIC circuits in 80-ies. FPGA contained only a few hundred gates and their operating frequency was 15 to 20 Mhz. The change was the defining principle of "do more with less" in 2009. Monetary limiting for defence and permit the use commercial technologies (COTS - commercial off the shelf) paves the way for PLD in military applications. The use of COTS technology whenever possible (resulting in a reduction in prices), resulted in increased use of FPGA in military applications [1].

2. WHY FPGA

Currently, the FPGA are used in the defence industry instead of ASIC circuits for the same reason as in the civilian sector: If the number of circuits that will be needed to implement the project, less than 100,000, the cost advantages are in using FPGA circuits. Also, the design cycle for FPGA circuits is shorter than the ASIC one. However, there is a group of applications where cost is not the most important parameter. One example is the area of intelligence and espionage, where, for example ASIC circuits will be chosen as a solution for the spy satellite, although the number of circuits are made up of tens, while the price for development can not exceed $ 50 million [2].

Configuration of the FPGA in field conditions is another advantage for military applications.

FPGA in the military communications device can be automatically deleted if device was lost or was captured by enemy. This is becoming less vulnerable in terms of reverse engineering and communications connection (or weapons systems). The main goal of the reverse engineering is to obtain information about the internal structure and modes of operation of the analyzed system.

Although there are no statistics that would monitor the FPGA circuit used in military applications (the market is small compared to the commercial use FPGA), the main FPGA manufacturers declare a significant increase in the use of these devices in military applications in the last decade. According to [2] defence industry is the fastest growing sector with an annual increase of 30 percent.

Equipment resistant to radiation is important for space applications. Radiation can cause changes in the status of the state flip-flop from logic 1 to logic 0 (or vice versa) and thus cause undesired change the behaviour of the circuit. Currently, the most important manufacturers offer devices resistant to radiation.

Manufacturers do not seek to produce special circuits for the defense industry, but offer improved properties that are required for military applications. One example is the operational temperature range. Range of industrial applications from -40 to 100 degrees Celsius, but for military applications range is from -55 to 125 degrees Celsius. This approach allows using the latest technologies in the defence industry and achieving the lowest prices compared with the approach which uses a product that was designed exclusively for military use. The two largest producers of circuit type PLD (Altera and Xilinx) bring new products to the commercial market and later a military version of the same type of product [3, 4].

An example would be 5Q Virtex from Xilinx, which is designed for aerospace and defence applications. It offers the possibility of implementing cryptography in one district (SCC - Single Chip Cryptography), which provides space for the development of secure communications systems for new generation. Given the circuit offers high performance, large capacity and rugged encapsulation. The main use of the circuit includes the following applications: secure communications systems, electronic warfare, aviation technology, C4ISR (Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance) systems, radars, missiles and smart munitions.

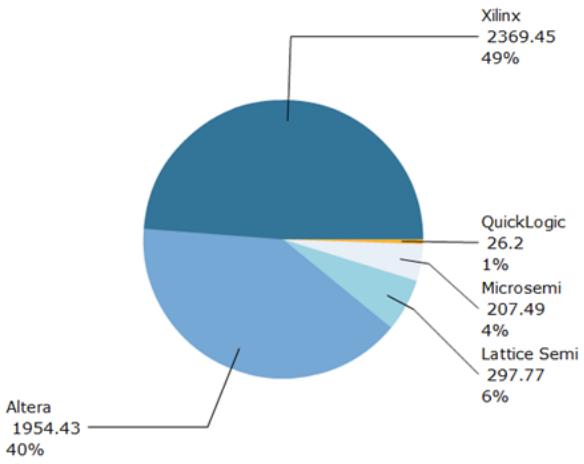

Fig. 1. FPGA producers and market share

3. ADVANTAGES OF THE FPGA

3.1 Possibility to adapt to any standard. In the case of modernization of the armed forces are always undergoing some risk. The armed forces are forced to in order to ensure interoperability using standards, but it is not always possible to correctly predict which standard will be dominant. The advantage of systems based on programmable circuits FPGA is flexibility and the ability and capacity to adapt to any standard. This can eliminate the losses incurred by the introduction incorrectly selected technologies and standards into the armed forces [5].

3.2 The length of the design process. Flexibility and adaptability offered by FPGAs are directly related to the length of the design process. ASIC circuits require a long design process - typically 14 to 24 months. The average time needed to implement the design for FPGAs is 6 to 12 months, which includes the specification, implementation, verification,

validation and prototype production. This is a significant time savings, which is important in the implementation of the critical applications and length of the design process sensitive applications and adaptation to new standards. Necessary design changes during the phase of using the device are implemented by reconfiguration of the FPGA. In the case of ASIC circuits, it is necessary to implement the complete design process from the beginning, which also includes the specification and verification [6].

3.3 Changing behaviour of the digital system without exchange of the hardware. FPGA can change the behaviour of the digital system without replacing hardware. All changes can be implemented through software means alone and reconfiguration can be performed even in field conditions. The flexibility is inherent in the FPGA, can reduce the price of the design and the price of used hardware. The ability to change the behaviour of the circuit and field conditions allows for a design with extremely flexible life cycle. The result is the possibility of rapid assimilation of new standards, allowing the armed forces fulfilment of set tasks and implementation of innovation with minimal delay. FPGA can be updated at any time, locally or via remote access. With partial reconfiguration can provide support, service, and an update on field conditions.

3.4 Increased performance of the computer system. Although part of the FPGA circuit is reconfigured, the rest of the circuit performs a defined action. This can eliminate the shortfall in functionality and performance of the circuit, which is reconfigured. Partial reconfiguration can allow implementation of multiple applications in a single FPGA. The implementation of multiple applications is switched at the time.

3.5 Sharing hardware. The implementation of multiple applications performing partial reconfiguration of one FPGA is a condition for allowing the sharing of hardware. The benefits that flow from it are as follows: reduce the number of necessary facilities, reduced power consumption, smaller size of the necessary circuit boards and lower overall financial costs of implementing the periphery.

3.6 The shorter the time needed for reconfiguration. The time required to configure the FPGA is directly proportional to the size of the configuration bitstream. Partial reconfiguration allows for a small modification of FPGA functionality without reconfiguring the entire circuit. Change only part of the configuration bitstream compared with reconfiguring the entire circuit can produce shorter total configuration time.

4. USE OF THE FPGA IN THE MILITARY APPLICATIONS

4.1 Unmanned aerial vehicles. FCS (Future Combat System) is one of the many modernization programs. Its aim is to provide cutting edge technology to the armed forces to enable them to dominate in complex environments of the modern battlefield. Part of this program includes a family of modular UAVs, which can be linked to a common network [7]. Unmanned is intended to carry out activities that pose a potential threat to people and save lives. These devices must be capable of performing search, survey and also must have the ability active influence to the

enemy. An example would be the situation when pilotless means gets into unexpected situations and remote operator needs to evaluate the video and audio in order to correctly assess the situation and to choose the right choice. To ensure that it is necessary to implement audio and video processing, which requires high-speed digital signal processing. Effective implementation of operations such "robots" is subject to the ability of listening and seeing, but also the ability to perform many orders. The abilities need to do intensive signal processing and use principles of artificial intelligence and require powerful hardware. Using conventional DSP processors to provide these capabilities has some limitations.

Conventional DSP processors have a fixed and unchanging architecture that contains one to four units of MAC (Multiply and Accumulate) with a fixed width of the data. Architecture then defines throughput, which determines the speed of processing. To increase computational efficiency of conventional DSP is required to increase their operating frequency to the maximum, which reduces the requirements for system design. Subsequently, several DSP processors must be included in processing, causing problems with energy and space on the target platform. The biggest advantage of using FPGA is its flexibility. For the application circuit can be configured so that the processing was carried out in parallel with the desired degree of parallelism. This may increase the maximum data throughput and optimize system performance. FPGA reconfigurability is a feature that is in demand for unmanned aerial vehicles. Plan prepared in advance for the use of UAVs in touch with the reality of the environment in which it is used, it must be changed frequently. FPGA has an ability to adapt to changes in behaviour flexibly and quickly to increase the probability of survival on the battlefield. FPGA reconfigurability enables end users to upload a new configuration for carrying out certain tasks within a specified time. Instead of implementing the system with a dedicated hardware for each specific task, it is possible to design a system with a single FPGA, which is used to implement multiple applications or tasks.

4.2 Unattended Ground Sensors. Unattended Ground Sensors are represented by the family of devices for implementation of remote sensing, that are interconnected by wireless network. Autonomous ground sensors (APS) can be used in defence of the designated perimeter for detecting and identifying targets and early warning. The size (the smallest size) and minimum power consumption resulted in a high degree of integration. Some sensors (sensor type FLIR - Forward Look Infrared) require intensive processing of information received, as opposed to requirements that are not asked. The amount of information that is sent to the communication line is also limited, and its compression is required. Information is processed before receiving, to avoid sending image that has not been changed. Flexible customization of computer performance can affect power consumption and system size. The solution to these requirements is a system with a high degree of integration. The last generation FPGA on-chip contains many features that were previously performed by software (soft core). High-speed I / O are a good example and some FPGA manufacturers integrate on-chip banks gigabit transmitters / receivers, Ethernet interface and PCI Express. Using these circuits can be integrated with external devices and sensors can be realized with a minimum of discrete components. Internal sources that would be used to implement these functions can be used to implement other parts of the design. FPGA can be implemented as an integrated solution. For most sensors is sufficient to capture the periodic "snapshots" over a defined period of time. It is necessary to generate a continuous stream of information from these sensors, which can represent movement of persons or vehicles. We also use the hardware (implemented FPGA) may be staggered partial tasks of data collection, processing and transmission of data. This allows the consolidation of a single device, resulting in a reduced size printed circuit boards, cost and power consumption.

4.3 Software Defined Radio. U To secure voice, data and video communications for U.S. forces, coalition forces and allies unit was defined vision of the Ministry of Defence to implement unified communications in real time. Transformation programs (JTRS - Joint Tactical Radio System) was created to eliminate the constraints and gaps between communication systems that can prevent the fulfilment of that vision. JTRS system is designed to ensure interoperability between modern and older systems through software programmable radios designed to ensure modularity, scalability, backwards compatibility and networking capability. Software-defined radio (SDR) includes a software programmable operating environment and can support multiple waveforms, made by a single system. The main constraint for the practical implementation of such systems are costs and requirements for power consumption.

The SDR is currently implemented in a dedicated model, which requires a set of sources for each implemented channel. Each channel represents one type of modulation defined radio. Each modulation (waveform) is realized by sources to carry out processing. Typical single-channel SDR modem includes AD and DA converters, FPGA, DSP and versatile processor (GPP - General Purpose Processor). This represents at least four discrete devices, which must be multiplied by the number of channels SDR. The result is increasing costs and demands on energy consumption with increasing the number of channels. This implementation of the SDR is not effective for general use. Another way is to implement a model of shared resources. This model is able to implement several modulations that are using one set of equipment for processing. This method is fundamentally different from the previous method, which required appropriations for each channel. FPGA, which is partially reconfigurable, allows the sharing of hardware. Partial reconfiguration can allow reprogram selected parts of the FPGA circuit to implement the operations defined in user-defined time after the initial configuration of the circuit. Accordingly, it is possible to implement several modulations in one FPGA. These circuits allow the user to dynamically change the modulation used without damaging the current modulation. Using the FPGA reduces the two main constraints that prevent the spread of the use of SDRs. Funding is investigated by integrating the components required to implement multi-channel SDR. Power consumption is also lower because the unused computing resources are eliminated. The result is longer battery life, which is used to power mobile SDR system.

5. CONCLUSIONS

The modernization process of the armed forces may accelerate the use of FPGA. The length of the design process FPGA is shorter by 55% compared with the design process of ASIC circuits. FPGA permit to integrate user-defined logic functions, DSP functions and multi-processors of GPP (General Purpose Processor) and requirements to reduce energy consumption and cost. Reducing power consumption allows the use of such systems in field conditions, where electricity supply is carried out with the batteries. By integrating multiple discrete devices into a single FPGA can be made portable systems that are lightweight and relatively small size.

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