The Method of Software Adaptive Testing on the Base of Goal Platform

D.I. Kardash
Computer Science and Information Protection
Ufa State Aviation Technical University
Ufa, Russia
e-mail: kardashdi@narod.ru

A.I. Frid
Computer Science and Information Protection
Ufa State Aviation Technical University
Ufa, Russia
e-mail: arkfrid@mail.ru

Abstract[1]

The analysis of programmed logic integrated circuits life cycle is resulted with the purpose of definition of control systems adaptation technological bases. The technique of adaptive testing of the software on a target platform and it realizing computer structure is offered. As the basic quality of control systems criterion the computer productivity and time of its adaptation is considered.

1. Introduction

Modern embedded control systems are constructed on the basis of the specialized processors. They should function in conditions of changing requirements to functionality and computing cores characteristics. Therefore the most importance gets an adaptive character of program and hardware of control systems (CS). Thus adaptability to changing requirements and conditions of operation is considered. In these conditions the development of calculator adaptation mechanisms becomes actual.

The processes of program and hardware updating of modern CS are interconnected with each other. Computers hardware at programmable logic device (PLD) use is described by means of hardware description languages (HDL.) HDL in essence are programming languages. It allows to relate the problems of equipment testing to problems of software testing. Therefore further we'll discuss the problems of software testing and diagnostics organization taking into account that the essence of offers can be transferred on the control system hardware.

The aspiration for achievement of the greatest time and qualitative benefits requires realization of testing on a target platform. Generalization of testing and adaptation mechanisms as a uniform technique of adaptive software testing (and equated to it hardware) on a target platform will be valuable.

2. State of the problem

The composition adaptation consisting of software updating and hardware reconfiguration is considered. As the causes of adaptation it is possible to specify change of the technical project, change of control object characteristics, maintenance of serviceability of embedded control systems or improvement of its characteristics. The specialized processors are realized on PLD base. They may be realized on the basis of Field-Programmable Gate Array (FPGA) or Application-Specific Integrated Circuit (ASIC) architectures. Areas of use of these PLD types are various, however they can be used together in uniform production cycle. In this case the stages of the development of the specialized calculators can be represented as PDCA cycles enclosed each other (see fig. 1).

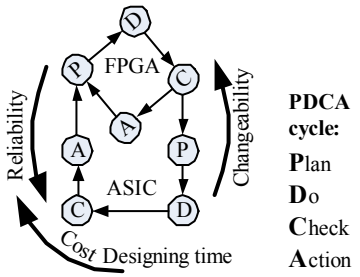


Fig. 1. The cycle of specialized computers development

For realization of adaptive opportunities of computers it is necessary to determine the ways and componential base for its carrying out. Stages of the resulted life cycle (fig. 1) of modern integrated circuit (IC) are submitted in table 1. In it the place of reconfiguration in life cycle of the specialized computers is shown. In it the results of advantages and drawbacks analysis of each of these stages are described.

Supported by President of Russian Federation grant ScS65497.2010.9, RFBR grant №08-08—00357
Proceedings of the 12th international workshop on computer science and information technologies CSIT'2010, Moscow – Saint-Petersburg, Russia, 2010

Table 1. Place of reconfiguration in life cycle of modern IC

N	Type	Essence	Advantages	Drawbacks
1	P_{FPGA}	Development of PLD configuration.	Simplicity of development and convenience of use of various manufacturers IP-blocks.	High probability of fault entering.
2	D_{FPGA}	Construction of the adapted hardware prototype.	The prototype can be repeatedly changed and adapted to concrete conditions of exploitation.	Complexity and periodicity of verification increases.
3	C_{FPGA}	Experimental or working exploitation.	Possibility of project adaptation during service.	Low (in comparison with ASIC) equipment reliability.
4	A_{FPGA}	Adaptation of the project by exploitation results.	High degree of adaptability.	Need for additional verification.
5	P_{ASIC}	Development of ASIC configuration. Preparation of manufacturing (photo masks).	Possibility of specialized computer development under requirements of application sphere.	High cost and the requirement of great volume of the order.
6	D_{ASIC}	Production semicustom IC.	Low cost at a large-lot production.	High cost of a mistake, preparation and verification of the project. Production is unsuitable to the further adaptation.
7	C_{ASIC}	Working exploitation.	High reliability due to absence of the external or internal memory realized by flash-technology.	Impossibility of project adaptation.
8	A_{ASIC}	Transition to the new device creation on the basis of the mistakes revealed during service or miscalculations in the project.	Actualization of computing cores functionalities.	Full refusal of former project on PLD configuration.

At joint FPGA and ASIC application FPGA are considered as tools of realization of ASIC configuration prototype or debugging of IP-blocks (intellectual property blocks). It is evident from the fact that after ASIC manufacturing change of its configuration is impossible. In case of need of the following prototype manufacturing repeated manufacturing a semicustom microcircuit (line 8, table 1) is required. It will lead to significant rise in price of the project because of alteration of rather expensive components - photo masks of microcircuits. Also it will lead to time characteristics deterioration of the project. But this stage of a cycle is rare and supernumerary. If the dynamics of control system changes is high then advantage belongs to FPGA architecture (lines 3 and 4, the table 1). From the table follows that for *firmware reconfiguration problems* at change of requirements or conditions of operation the most comprehensible is *FPGA architecture*.

However increase of application and reconfigurability CS flexibility results increase of probability of malfunction entering by the developer. Malfunctions can be brought both into the software and into the configuration information. Also it is promoted by aspiration to reduce time characteristics of the project. Thereby there is a need to carry out the control and diagnostics of adaptation processes. In some cases a state of control object and parameters of its control system are nonstationary. It results to necessity of debug, control and diagnostics directly on a target platform. In more details the importance of control and diagnostics at adaptation processes of software is shown in [1, 2].

Except trivial benefits of PLD application it is possible to allocate some specific advantages in testing organization. **One of such advantages** is the opportunity of optimum computing tasks distribution between program and hardware maintenance of the specialized computer. At FPGA application the processes of program and hardware updating are shortly interconnected with each other. During preparation of equipment prototype hardware changes can be frequently take place. It will inevitably cause the necessity of software updating. Or on the contrary: during software modernization the requirements to functionality computing core updating can be formulated. It allows to expand the opportunities of adaptation and also to reduce the time of control tasks decision due to their optimum distribution between software and hardware of control system firmware.

Other specific advantage is that the way of software description is similar to the way of modern equipment description. So, PLD are configured by means of hardware description language. As a result it is possible to consider the equipment as programs. It allows the developer to test the equipment as the program that sharply reduces time of development and testing.

The offered technique of software adaptive testing on a target platform is intended for reduction of CS reconfiguration terms and increases their productivity. It follows from the reduction of control cycle duration and time of testing. The greatest efficiency of its application can be assumed at embedded CS construction with the help of the componential base supposing reconfiguration ability (for example, FPGA).

3. The technique of adaptive testing

For realization of faultless adaptation of embedded firmware its hardware part is offered to realize as three-cores structure (see fig. 2). The given structure is heterogeneous. The first computing core carries out the basic control functions. The second one debugs program or updates hardware. The first and the second computing cores are identical in a regular mode. But at updating moment the changes apply only the second computing core. In case of reception of required results during its reconfiguration the changes are transferred to the basic core. The functions of the third core: the organization of software control process, the control of execution results of reconfiguration on the bases of the parameters concerning control object, modeling of control object, decision-making on necessity of control system reconfiguration. For software checking it is necessary to model control object behavior. The third part of structure is an allocated diagnostic core.

The technique consists of three large stages: static, dynamic testing and the analysis of results.

1. A stage of static testing. At this stage software testing activity without its pre-production operation in an embedded control system is provided. Static testing is carried out in order to determine if control system correctly realizes all requirements of basic or modernized technical project. Static testing is carried out at a stage of control system debugging in tool programs of development and on hardware emulators according to accepted for the chosen type of microcircuits design flow.
2. A stage of dynamic testing. This stage represents the activity providing operation of software product on a target platform. For this purpose in the structure of offered specialized computer it is stipulated test core on which check is carried out. Check of modernization results containing possible mistakes is carried out not on control object but on its model in real time that provides safety of functioning CS.
3. The analysis of results. The analysis of control system functioning results is intended for decision-making on commissioning. The stage provides the procedure of measurement of software quality parameters concerning control object. In case of satisfactory results of the analysis the accepted program is entered into the structure of adapted software functions, otherwise - is rejected.

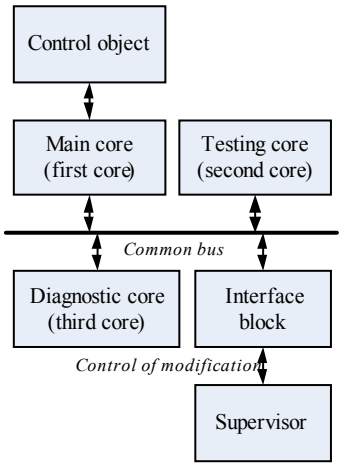


Fig. 2. Structure of adapting computer

The organization of the second and third stages is assigned on diagnostic core. On fig. 3 the timing illustrating an essence of given technique is submitted. On it the loading of three subjects of updating process is shown: software developer and three computing cores of the specialized computer. As an example occurring transfers of management are resulted at revealing two mistakes during modernization.

The offered technique can be formalized as the following five steps.

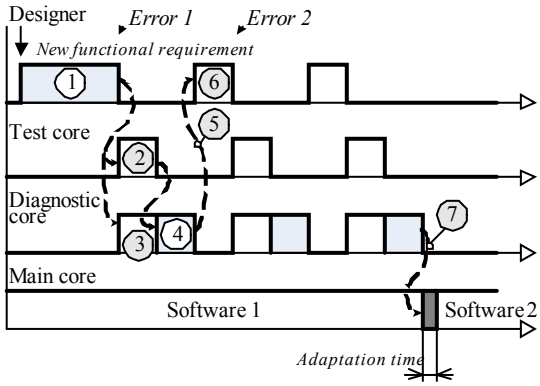
Step 1. Initial development (number 1 on fig. 3) corresponding to new or modified functional requirements. On this step static testing on universal computers and emulators is carried out.

Step 2. The result of development is transferred on test core. Simultaneously diagnostic core becomes more active for supervision over testing process (number 3).

Step 3. Diagnostic core carries out the estimation of software quality (number 4). In case of a mistake detection or discrepancy to requirements the project returns to the developer (number 5) for correction of discrepancies on step 4 of techniques. In case of satisfactory results transition to step 5 is carried out.

Step 4. The developer carries out correction of the project (number 6). On this step elements of static testing also are carried out. Transition to step 2 is carried out.

Step 5. The result of testing is transferred the basic core for execution with real control object (number 7).



1 - a stage of static testing;
2 - a stage of dynamic testing;
3 - supervision over dynamic testing;
4 - analysis of results;
5 - transition which is carried out in case of revealed malfunctions;
6 - updating the program by the developer;
7 - decision-making on software replacement.

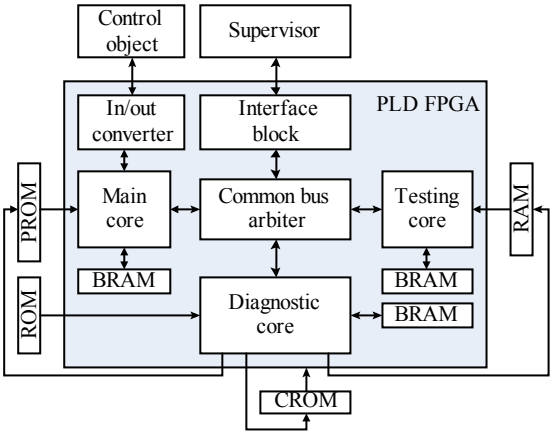
Fig. 3. A technique of software adaptive testing

The basic ideas underlying described technique have been protected by the patent for the complex invention [3]. Its application for reengineering of managing programs is submitted in the publication [4].

3. Technique realization on the bases of three-processor specialized computer

Described technique realization on the basis of the modified three-processor computing system is offered [3]. We consider that the most favourable and rational its manufacturing is on the PLD FPGA base. In this case to adaptation can be already subjected not only software but also equipment. The structure of offered specialized computer is resulted on fig. 4.

Configuration memory (configuration ROM, CROM) is intended for storage of PLD FPGA structure information. The information in it can be changed by diagnostic core in full or in part. It solves a task **of hardware adaptation** of control system. In given structure the use of built - in PLD operative memory blocks (block RAM, BRAM) is shown. In case when size of these blocks is insufficient for realization of management computing cores algorithms external memory can be connected.



RAM - random access memory;
ROM - read only memory;
CROM - configuration ROM;
BRAM - block RAM (internal in PLD);
PROM - programmable ROM.

Fig. 4. Realization of adapted specialized computer

It is necessary to note that at worst the structure includes seven separate memory devices. They can be grouped in smaller amount of microcircuits. But in this case realization of memory arbiter is required. It will lead to deterioration of functioning time characteristics and complexity of PLD configuration. Most probably the size of operative memory PLD block allows to carry out managing algorithms. Realization of non-volatile memory in PLD structure is technologically inconveniently and not favorably. That is why the READ-ONLY STORAGE is realized as external IC. Programmable memory (programmable ROM, PROM) is intended for storage of the managing program that is acknowledged efficient during testing. PROM of the basic computing core has identical architecture and dimension with RAM. This memory comprises the tested managing program. It can be realized also as PROM but if it is realized as RAM it allows to improve testing process essentially. Software of diagnostic core is situated in constant memory ROM. Change of this program during adaptation of computer is not supposed. Also ROM can keep a copy of obviously suitable managing algorithm. This copy can be a need for restoration of device normal work in case of mistakes of updating.

The offered structure of a control system represents practical realization of the structure shown on fig. 2.

4. Conclusion

Offered technique of software adaptive testing and the structure of adapted specialized computer allow to

provide the protection of controlled object against possible brought program mistakes in managing software. Processes of modified program check and functioning of unmodified program proceed in parallel. Such way allows to reduce and even to avoid undesirable stands idle in work of control system.

The following results are received:

- The offered technique allows to carry out controllable process of adaptation of the specialized computers at in-circuit (in-system) programming that essentially reduces the duration of adaptation and CS testing by embedded systems.
- On the basis of carried out analysis of PLD architectures, offered three-processor structure and the developed technique the structure of the reconfiguration computer has been developed. This computer allows to expand opportunities of its adaptation on program and hardware level.

The submitted results serve to decision of such problems as: increase of CS productivity due to optimum distribution of tasks between software and hardware; reduction of time of such optimization carrying out due the use of firmware technique testing on a target platform. As a result we can expect reduction of control cycle time, improvement of control quality by embedded electronic systems and also reduction of time of their actualization (in reply to change of control object state, technical requirements and conditions of operation).

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