Model of microcontroller for education purpose

Alexander Timofeev[1], Pavel Ushakov

[1] Siedlce University of Natural Sciences and Humanities,
Institute of Computer Science
Sienkiewicz st. 51, 08-110 Siedlce, Poland

Abstract: It is emphasized that simulation modeling of compound electronic devices is one of the effective methods of education and training of electronics engineers, but the problem of wide time to waiting of results in simulation modeling of compound electronic devices come into being. Programming system Amethyst design compound models, for which the waiting time of results is in reasonable limits. The model of microcontroller PIC18F6720, which is used on lessons "Embedded systems", is described and results of experiments with the model are presented. Experiments with the model lead to the conclusion that the model can be used in the process of education and training of electronics engineers.

Keywords: Simulation modeling of compound electronic devices, model of microcontroler PIC18F6720, education and training of electronics engineers.

1 Introduction

Simulation modeling is one of the effective methods of education and training of electronics engineers.

Experiments on the microcontroller model allow to debug as hardware, and software , quickly change the parameters of the model (timing parameters, the contents of the registers, RAM, ROM, etc.), including the and to enter a fault in the circuit check the operation of the devices in critical modes and without its destruction due to careless actions of students, give the possibility to "see" changes the state of the internal elements, allow to understand how the microcontroller executes the instructions, recorded in his program.

The use of industrial circuit CAD requires large overhead costs and time-consuming for their acquirement by students, and these CAD are not focused on the education process and are designed for a professional engineer.

From the point of view of use of modeling for training to designing computing and control devices the simulation system Amethyst has the following advantages:

– cheapness and functioning on widespread computers;
– the open interface for the user, possibility to create models with the required degree of adequacy, possibility to create models of any components and functional units, including with conventional control inputs for the definition of faults;

- possibility quickly to change the parameters of the model (timing parameters, the contents of the registers, RAM, ROM, etc.), including the and to enter a fault in the circuit;
- use of C language that, first, allows to address to ports of the computer and, thus, to make the circuit modeling using real blocks, secondly, does not require the study of special hardware description languages;
- creation by simulation system EXE-files for the simulated circuit that allows to transfer these files to other computers without re-modeling of the circuit;
- junction of possibilities of a debugger of the software and usual functional-logic simulation system;
- visualization of results (the possibility to display the names of machine cycles, mnemonic commands are executed, the contents of the internal registers, RAM, ROM in any number system, the voltage levels on the pins of the components, the signal change time etc. along with timing diagrams, the possibility of error messages);
- possibility of the modeling of the compound analogue - digital circuits.

On a way of modeling of microcontrollers there are great difficulties:

firstly, it is not easy to write the program which simulates the microcontroller, at least for the reason that in the documentation functions of blocks of the microcontroller are often described, and not their implementation;

secondly, because on such program rigid restrictions on time of its execution are imposed, as in the process of education the user interacts with the program in a dialogue mode.

The model of microcontroller PIC18F6720 of firm Microchip and results of experiments with model are described below; problems of modeling of compound electronic devices are thus touched.

2 Microcontroller PIC18F6720 model

This described program model of microcontroller PIC18F6720 could be called the "demonstrative" model, as the model not only simulates function of the microcontroller taking into account delays, but also shows on the screen the status and parameters, interacts with the user, and also contains the simulator of the programming device (programmator).

The interaction with the user takes place at the stage of preparation of modeling, and also in the mode of imitation of the execution of the program of the microcontroller (in debugging mode).

The simulator of the programmator included in the model reads a file with the microcontroller program which has popular format Intel HEX32, and writes in variables of the model instructions, configuration bits, the identifier of the microcontroller and contents of the parameters memory.

The model is realized in the form of class C_e18F6720 which inherits attributes and functions of class C_baseUnit. Class C_baseUnit is the base class in the simulation system Amethyst [1].

In the simulation system Amethyst [2] the model of microcontroller PIC18F6720 acts as a library element, and such element can be included in the model of more compound device.

Following three files correspond to the model of the microcontroller PIC18F6720, as to each library element of the modeling system Amethyst:
1) amethyst-file with the description of the model;
2) header file e18F6720.h with the description of structures and variables;
3) implementation file e18F6720.cpp with the description of the function of the model.

Files e18F6720.h and e18F6720.cpp contain the text in language C++ for Borland C++ Builder programming system. The amethyst-file with a model description is a text file and can have any of three formats:
− the text in expanded ASCII-code (filename extension ".ame");
− format RTF (filename extension ".rtf");
− format HTML (filename extension ".html").

In the amethyst-file text it is possible to apply pseudo-graphic signs. Because in the expanded ASCII-code (font Terminal) there is not enough pseudographics, the amethyst-file can be created in UNICODE (UTF-16) in RTF-format or HTML-format.

The user of the system Amethyst has the possibility to adjust the description of each library models, and for format change there is a special editor.

Variables which reflect the state of the model are concentrated in structure s_e18F6720, and variables that store parameters of the model, in structure sp_e18F6720.

2.1 Model description

The Amethyst-file with the model description contains sections:
− VERSION in which are specified the system version, date of creation of the description, the author, the owner;
− NOTE in which remarks take place;
− LEFT and RIGHT with the description of left and right pins of the model (microcontroller);
− STATUS with the text in which the model state is written;
− PARAMETERS with the parameters of the model;
− UNITS and NODE in which components of compound model and their connections are described (in microcontroller PIC18F6720 model these sections are empty).

Model shows contents of sections VERSION, NOTE, LEFT and RIGHT in the window "Information", section STATUS - in the window "Status", section PARAMETERS - in the window "Parameters", and sections UNITS and NODE - in the window "Scheme" in the form of the device scheme.

In sections STATUS and PARAMETERS each text line is divided into two parts between which characters "!#!" are placed. In the first part there is a text shown to the user, and in the second part the controlling text takes place.

The controlling text contains the data about fields, allocated in the shown text: field type, initial position, width and height of field, color of signs, color of background, repetition factor, step in case of repetition. In the process of the simulation the model writes actual values of the variables united in structures s_e18F6720 and sp_e18F6720 in the described fields. The fragment of section PARAMETERS is shown on fig. 1.

Device IDs									

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit0	
3FFFFE	DEVID1	DEV2 0	DEV1 0	DEV0 1	REV4 0	REV3 0	REV2 0	REV1 0	REV0 0	!#!symbol:green(20/1*8/7)
3FFFFF	DEVID2	DEV10 0	DEV9 0	DEV8 0	DEV7 0	DEV6 0	DEV5 1	DEV4 1	DEV3 0	!#!symbol:green(20/1*8/7)

Figure 1. Fragment of the section PARAMETERS of the model of microcontroller PIC18F6720

The description of the state of the model is created on the basis of the functional scheme, presented in the data sheet.
The typical structure of a section of the STATUS:
in the beginning of the snapshot the image of the object as a "black box" with the actual values of the inputs/outputs, then
the functional scheme at the level of registers with the added fields, and then
the image of subcomponents of the microcontroller.
View of sections with the description of the model depends in the system Amethyst only on the author of the model. Fig. 2 and 3 illustrate how the user sees state and parameters.

2.2 Function of model

Function of the model is described in files e18F6720.h and e18F6720.cpp in C++ language. Subroutines (functions of the class) fCreateStructure(), fSet(), f1(), f2(), fUpdate() form a group of subroutines, which are defined in the base class as virtual functions and can have an implementation of the model class.
Class function fCreateStructure () is called only once at the beginning of the simulation and serves to import data from a file with the description of the model.
Class function fSet() resets the state of the model and is called at the beginning of the simulation, as well as when clicking on the button "Reset".
Class function fUpdate () is responsible for the display of windows of the model.
Class functions f1() and f2() are called during the simulation at moments of approach of events. These functions correspond to two phases F1 and F2 of calculation of the new state of the model: in the phase F1 components of the model output

signals on connecting lines, and in the phase F2 is analyzed the state of inputs and the state of the model changes [2].
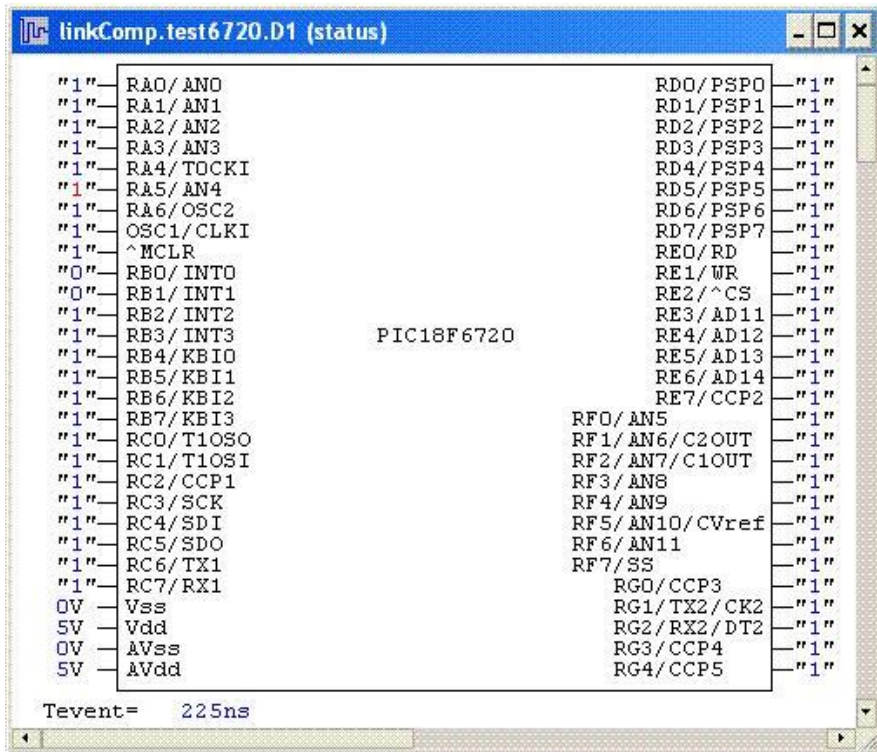

Figure 2. The state of the model in the window "Status"
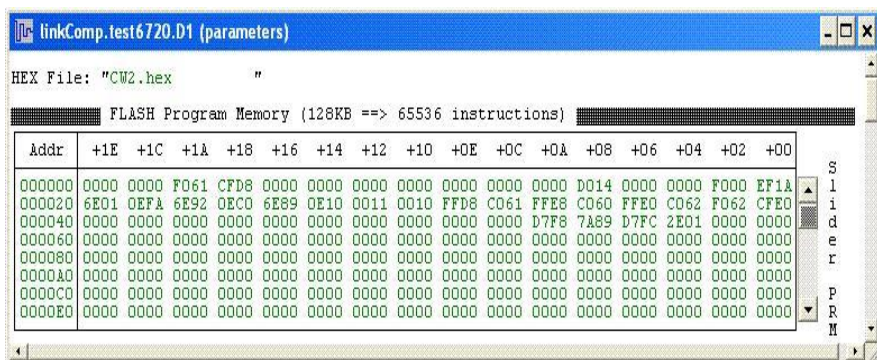

Figure 3. Parameters of the model in the window "Parameters"

In the process of simulation at first are called functions f1() of all components of the model, and then functions f2(). Such strategy provides the correct results of simulation in the case of wired connections of pins of components.

The structure of the model of the microcontroller corresponds to model "ideal function - delay on outputs".

The execution of commands of the microcontroller is concentrated in the function f2(). For the implementation of the 4-state machine cycle the finite state machine by 8 states is used. Sync signal of the machine comes from the generator, which is switched in phase F1 (in function f1()) on a condition "actual time equals to system time".

The generator, as well as filters for outputs represent the implementation of the F-model proposed by A.Timofeev [3].

Microcontroller modeling has revealed a problem of a sleep-mode simulation. In this mode in the real microcontroller the generator of sync signals does not work. There is the problem, that the generator in the model cannot be "switched off", because events will cease to be created and the simulation process will end.

In the considered model in a sleep-mode the generator does not switch off, and the model analyzes interrupt signals.

3 User interface

The user interacts with the model in the main window (Fig. 4). In the window the user sees actual time of modeling in the field "Time", time of the nearest event in model in the field "Event".

In the field "Command" it is possible to choose one of modes of the simulation and to set its parameters:

"Events" (from event to next event),

"Interval" (during the set interval of time),

"To time" (with a stop at the set moment of time),

"End time" (to the end of the simulation time).

Clicking on the button "Simulation" causes the process of simulation (modeling), on the button "Reset" - brings to return to the process beginning, on the button "Pause" - interrupts the process until the new clicking on the "Simulation".

In the field "Breakpoint" parameters of the breakpoint are set by the value of the variable in the model.

In the field "Structure" the structure of the model is shown. As can be seen in Fig. 4, the model of the microcontroller D1 is located within the model of the component "linkComp", and at the same level with the microcontroller is an additional component - the recorder.

The recorder can show timing diagrams and may be connected to each variable in the model.

Files for the component "linkComp" and for the recorder are created by system Amethyst (the program amethyst.exe) on the basis of texts - drafts. The component "linkComp", inherent in all models in system Amethyst, is designed for partition of the "universal" part of the system and of the "special part", to which the microcontroller belongs.
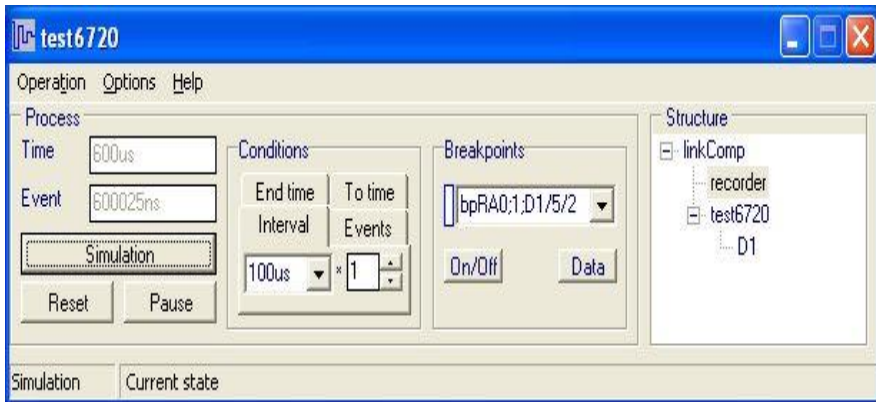
Figure 4. The main window of the model

The main window menu duplicates the control from graphic elements, but also allows to set the parameters of the display process.

4 Results of experiments

Experiments with the model had to give an answer to the question, whether it is possible to use the described model of the microcontroller PIC18F6720 in the process of education.

For experiments the program which students create on lessons "Embedded systems" has been chosen. The program sends a signal to the speaker in the form of a meander at a frequency of 4 KHz.

Clock frequency of the microcontroller 40 MHz has been chosen that gives effective time of a machine cycle equal 100 nanoseconds.

The recorder of events has been connected to the pin RA5 of the port A.

The received timing diagram of a signal (fig. 5) has the form of a meander with the period of 250 microseconds that corresponds to the task.

The simulation time during 5 ms of a model time amounted to 41 seconds on the computer with the processor 2 GHz with display only a final state in two windows (in a window of a state of the recorder and a window of a state of the microcontroller). During 41 seconds in the model occurred approximately 200000 events at the execution of approximately 50000 instructions.

In an animation mode, that is at display of states of the model and the recorder after each event, 10 minutes on the process of 58 microseconds (approximately 2320 events) were required.

Experiments with the model of the microcontroller PIC18F6720 lead to the conclusion that the waiting time of results is in reasonable limits.
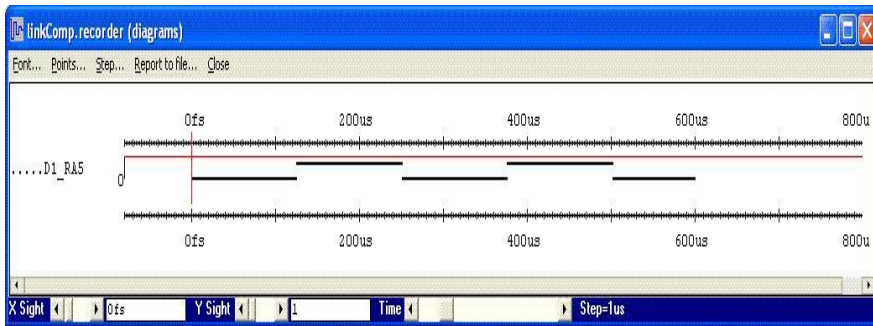
Figure 5. Timing diagram

It is necessary to consider that the experimental model did not contain simulators of the interface blocks. However, the addition of such blocks will increase the simulation time slightly for the reason that the number of branches will increase in the program, and linear sequences of instructions will remain without significant changes.

5 Use of "demonstrative" model for education purpose

The model of the microcontroller PIC18F6720 is used on lessons "Embedded systems" for future electronics engineers.

A student is received the task: design of a device scheme included microcontroller.

Debugging on the microcontroller model allow quickly change the parameters of the model (timing parameters, the contents of the registers, RAM, ROM, etc.) without device destruction due to careless actions of student, give the possibility to "see" changes the state of the internal elements, allow to understand how the microcontroller executes the program instructions.

Results of student job are timing diagrams in characteristic points of designed device.

References

1. Timofeev A. O., (2006). Basic solutions for a program system for dynamic systems simulation. In: Studia informatica: systemy i technologie informacyjne, vol. 1/2(7), 2006, pp. 255-263.
2. Timofeev A. O., (2004). Computer production of programs for simulation of dynamic systems. In: Proceedings of the 15th International Conference on Systems Design (7-10 September 2004, Wroclaw, Poland). Vol. 2. Pp. 91—95.
3. Тимофеев А.О., (1985). Функциональная модель технического устройства (Ф-модель). In: Электронное моделирование, 1985, vol. 7/1, pp. 86-91.