Design of POP-11 (PDP-11 on Programmable chip)

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Abstract— We developed POP-11/40 which is PDP-11/40 compatible processor, implemented it on an FPGA. We also designed ANSI C development tools an FPGA base-board which has SRAM, Serial and IDE interface, and run UNIX V6 on this system. In this paper, we describe a feature of a design of POP-11/40, base-board and UNIX V6.

I. Introduction

In 2002, UNIX licenses for 16-bit processor became to open-source by Caldera Inc[1]. UNIX V6 is well described in *Lions' Commentary on UNIX*[2]. The book has been used as case study of real operating system in many universities. UNIX V6 was run on PDP-11, developed by Digital.

We developed POP-11/40 (PDP-11/40 compatible processor), and it can run UNIX V6 on an FPGA.

II. Design of POP-11/40

POP-11 has all of PDP-11 features with hard-wired logic. The philosophy of the development is implement on an FPGA compactly. The block diagram and data path diagram of POP-11/40 is shown in Figure 1. It's designed as state machine shown in Figure 2 to reduce logic gates. PDP-11 has many addressing modes, we designed it with the flow shown in Figure 2, it realized with minimum logics.

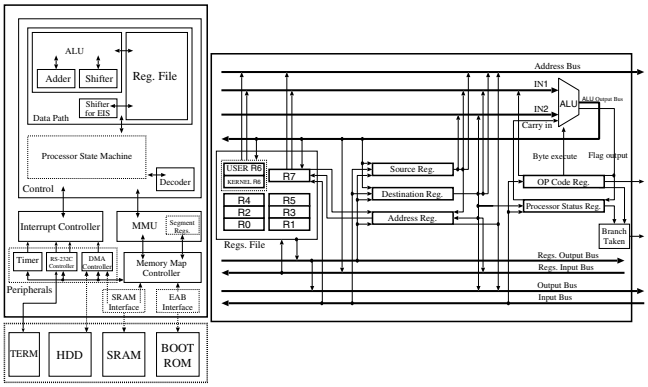

Fig. 1. Block diagram of POP-11/40

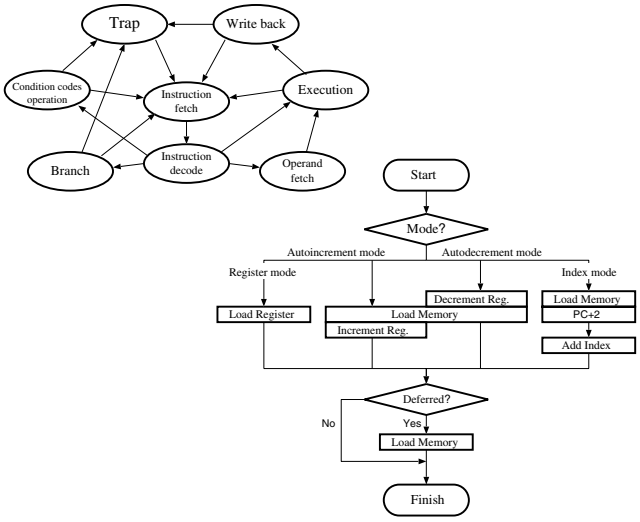

Fig. 2. State transition and Addressing modes processing of POP-11/40

POP-11/40 processor includes peripherals: timer, RS-232C controller, hard disk controller, and interrupt controller, which are required to boot UNIX.

The development environment of POP-11/40 is shown in Table I. These tools are freely available, and useful to realize SoC. The source code of POP-11/40 processor is less than 3,000 lines in SFL, and then we convert SFL source code to Verilog HDL with sfl2vl[3]. Finally we use Verilog HDL source code for simulation and synthesis.

TABLE I
Development environment

Language	SFL
SFL compiler	sfl2vl
Simulation	Icarus Verilog, GTKwave
Synthesis	QuartusII3.0 Web edition

The summary of the implementation on an FPGA is shown in Table II.

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TABLE II
SYNTHESIS AND FITTING RESULT ON AN ALTERA FPGA

Logic Elements	MAX Frequency	Device
2761 LEs	10 MHz	Cyclone EP1C3

III. C DEVELOPMENT ENVIRONMENT

We adapted GCC and GAS as ANSI C development environment for PDP-11 architecture. We also ported the real-time operating system *proc*[6] which is developed for embedded system. These patches and ported files are also available from our web site.

IV. UNIX V6 SIMULATION

We simulated UNIX V6 with Icarus Verilog as cycle-base logical simulation. The executable simulation binary is able to be downloaded from our website[5]. The simulation binary can simulates UNIX V6 booting process in 20 million cycles.

V. DESIGN OF BASE-BOARD

To run UNIX V6 with POP-11/40, we designed FPGA base-board with Eagle[4]. The design layout is shown in Figure 3. The base-board has SRAM, RS-232C and IDE interface, and power supply, it's made from expose plate. ALTERA Cyclone EP1C3 has only 65 total pins, therefore we designed to share data bus of SRAM and IDE interface. The implementation photograph is shown in Figure 4.

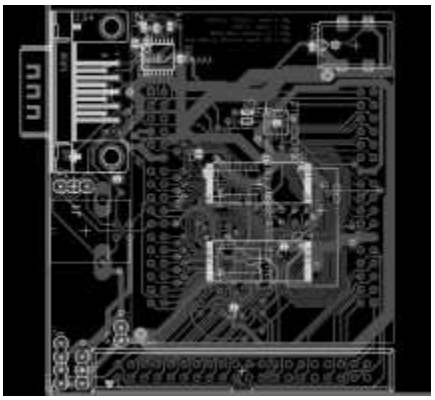

Fig. 3. The design layout with Eagle

VI. BOOTING UNIX V6

We used the cross-environment to develop a monitor program for POP-11/40. The monitor program is on the on-chip memory of the FPGA. And it will be activated when processor executes HALT instruction. Figure 5 shows that the monitor program screenshot when it dumps UNIX V6 kernel.

UNIX V6 disk image was stored HDD, when POP-11/40 is powered on, the bootstrap loader in the on-chip memory will start. And it will load first sector of the HDD into the address 0, and clear program counter. The first sector contains boot loader of UNIX.

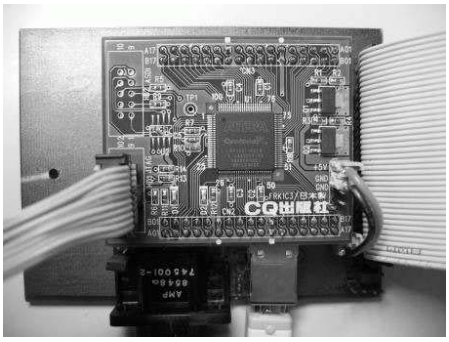

Fig. 4. The photograph of the base-board

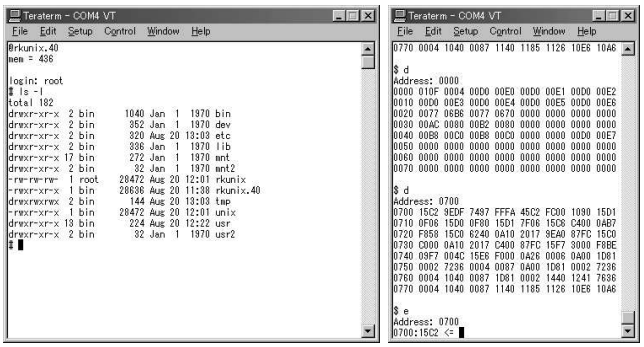

Fig. 5. Booting UNIX V6 and Monitor program

VII. CONCLUSION

We developed PDP-11/40 compatible processor named POP-11/40, it's can fit on an FPGA compactly and it can boot UNIX V6 from IDE HDD. We also designed ANSI C development environment for the processor, and the base-board of FPGA. POP-11/40 was designed with free tools and low price devices, and we designed the most part of the computer system. This system gives great motivation for study processor architecture, board circuit architecture, operating system and compiler.

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