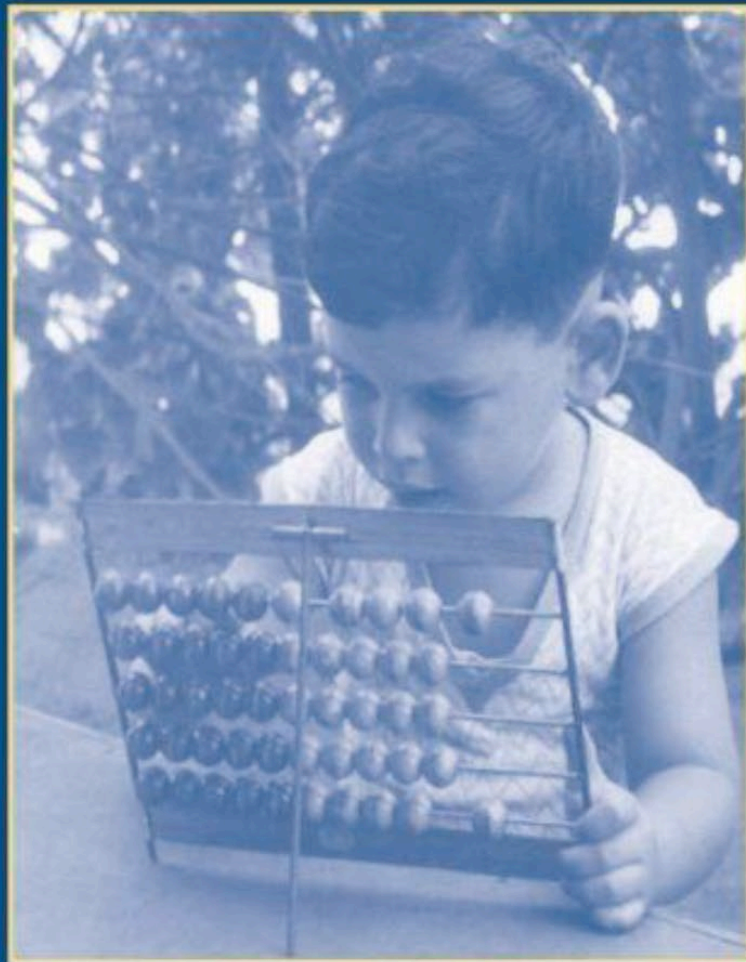


The Elements of Computing Systems

Building a Modern Computer
from First Principles



Noam Nisan and Shimon Schocken

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Note on Software

The book's Web site (<http://www.idc.ac.il/tecs>) provides the tools and materials necessary to build all the hardware and software systems described in the book. These include a hardware simulator, a CPU emulator, a VM emulator, and executable versions of the assembler, virtual machine, compiler, and operating system described in the book. The Web site also includes all the project materials—about 200 test programs and test scripts, allowing incremental development and unit-testing of each one of the 12 projects. All the supplied software tools and project materials can be used as is on any computer equipped with either Windows or Linux.

5.3.1 The Central Processing Unit

The CPU implementation objective is to create a logic gate architecture capable of executing a given Hack instruction and fetching the next instruction to be executed. Naturally, the CPU will include an ALU capable of executing Hack instructions, a set of registers, and some control logic designed to fetch and decode instructions. Since almost all these hardware elements were already built in previous chapters, the key question here is how to connect them in order to effect the desired CPU operation. One possible solution is illustrated in figure 5.9.

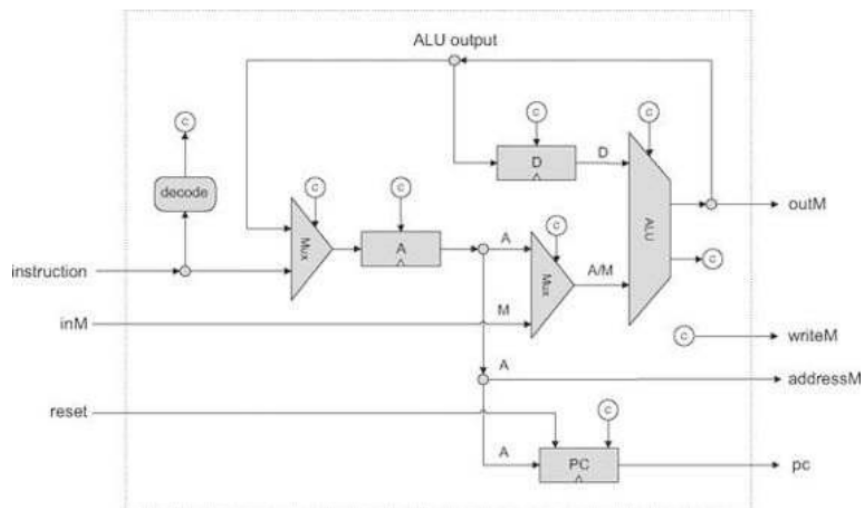


Figure 5.9 Proposed CPU implementation. The diagram shows only *data* and *address paths*, namely, wires that carry data and addresses from one place to another. The diagram does not show the CPU's *control logic*, except for inputs and outputs of control bits, labeled with a circled “c”. Thus it should be viewed as an incomplete chip diagram.

The key element missing in figure 5.9 is the CPU's *control logic*, designed to perform the following tasks:

- **Instruction decoding:** Figure out what the instruction means (a function of the instruction).
- **Instruction execution:** Signal the various parts of the computer what they should do in order to execute the instruction (a function of the instruction).
- **Next instruction fetching:** Figure out which instruction to execute next (a function of the instruction and the ALU output).

(In what follows, the term *proposed CPU implementation* refers to figure 5.9.)