Computers

by
Vojin G. Oklobdzija
Advanced Computer Engineering Laboratory
Electrical and Computer Engineering Department
University of California
Davis, CA 95616

A *computer* is a system capable of solving various scientific and non-scientific problems, storing retrieving and manipulating data, communicating and sharing data, controlling processes and interacting with the surrounding environment.

Today, typically a computer consists of a complex electronic system containing a massive amount of components which are very highly integrated. Even the simplest computer today is far more complex than the computers from not so distant past and often contains millions, or even hundred of millions of transistors. The micro-photograph of the IBM 620 microprocessor containing 7 millions of transistors is shown in the Figure 1.

Computers emerged from complex digital systems and controllers in the areas where the behavioral specification for such a system could have been satisfied with some sort of a general purpose digital system. One of the first mini-computers (18-bit PDP-4) was built as a generalization of an atomic plant controller. Similar faith was of the first microprocessor, Intel 4004 (S. Shima), which was originally commissioned as a generalized calculator chip.

Because of computers versatility and general purpose orientation there is hardly any place today that does not contain a computer in one or the other form. This is made possible by two facts:

(a) their structure and organization is general and therefore it can be easily customized in many different forms.

(b) because of their general structure, they can be mass-produced which keeps their cost down.

The four and eight bit microcontrollers which still represent over 90% of the microprocessors sold, are generally selling for way under a dollar which is due to the fact that they can be produced in very large quantities.

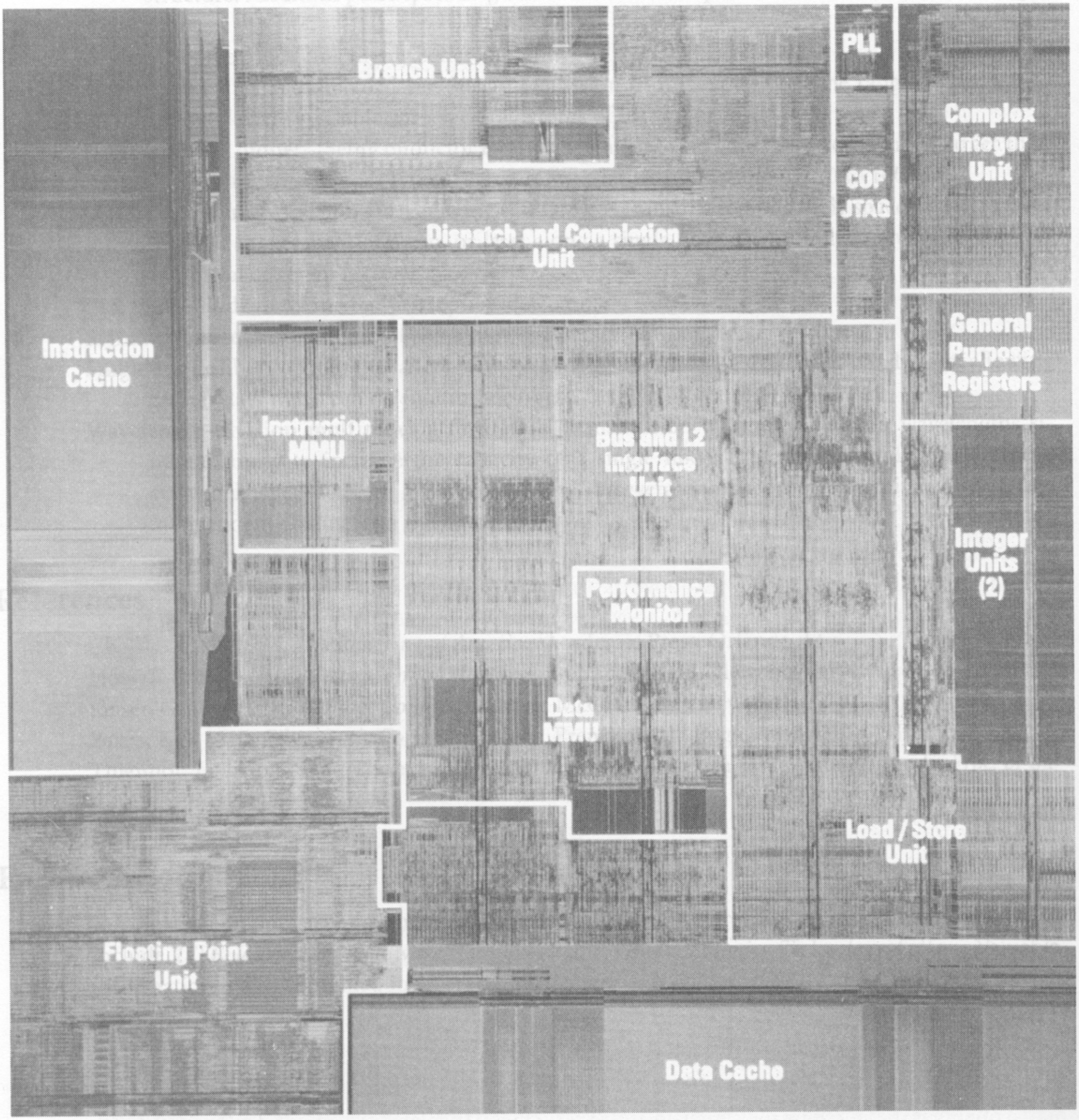
By their power computers are traditionally classified in 4 major categories: personal computers, mid-range or work-stations, main-frames and super-computers, though the boundaries between those categories are blurred. The reasons for that is that the same technology is being used for all four categories with the only exception being main-frames and super-computers which are resorting to bipolar and gallium arsenide. Therefore, the performance increases are being achieved mainly through the improvements in technology and the performance is roughly doubling every two years as shown in Figure 2. The changes in the architecture do not contribute to the performance increases because the architecture issue has been settled around RISC architecture and the machines utilizing RISC architecture have clearly demonstrated their advantage over CISC.

RISC stands for Reduced Instruction Set Computer while CISC stands for Complex Instruction Set Computer. RISC is characterized by simple instructions in the instruction set which is architected to fit the machine pipeline in a way in which one instruction can be

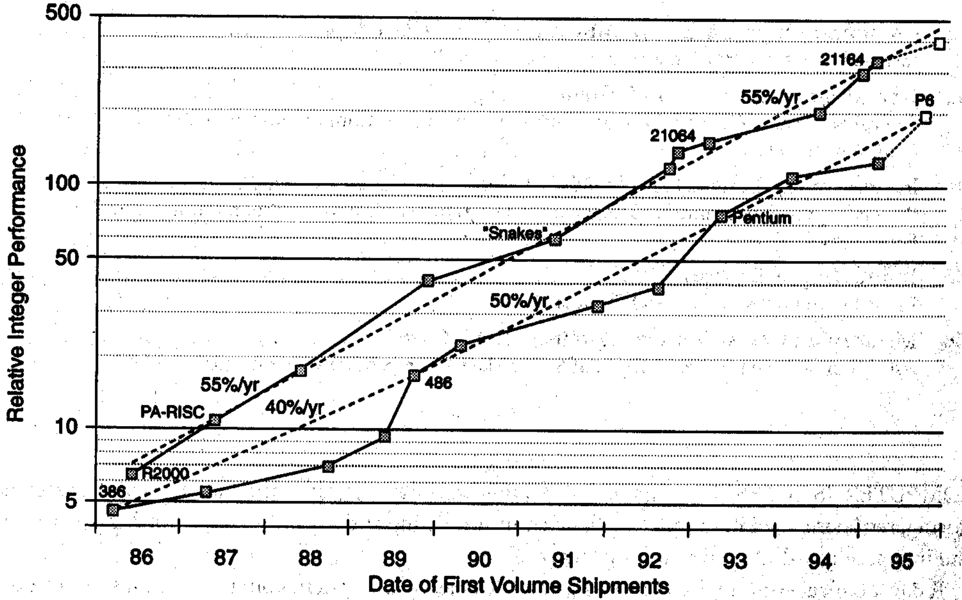
issued in every cycle. The characteristics of CISC are complex instructions which have grown mainly out of the micro-programming design style of the computer.
Another distinguished computer class are so called *"Super-Computers"*. They are the ones that have been driving all of the advanced concepts in architecture as well as being the vehicles for driving the technology to its limits. Though we had several computers being designated as "super-computers" in the past, such as IBM-Stretch, IBM System 360 Model 91 and Control Data's CDC 6600, the real era of "super-computers" started with CRAY-1 engineered and designed by Seymour Cray. Probably the best description of a super-computer is a design where the performance is the prime objective and the cost is being ignored. They are manufactured in small numbers for very special customers requiring very high performance and willing to pay a premium cost for that performance. The first CRAY-1 was introduced in 1976 and had a clock cycle of 12.5nS. The latest CRAY is the CRAY-4, built in gallium arsenide technology with the cycle time of 1nS capable of achieving 256 gigaflops in a 128 processor configuration. CRAY-4 is truly a state of the art in almost all of aspects of engineering.

Today, a typical high-performance computer system employs more than one processor in various arrangements. There has been a long effort to parallelize the execution of the programs and take advantage of the number of relatively inexpensive processors in order to achieve a high processing rate. These efforts, up to today, have been met with a limited success. A number of parallel machines have been introduced with a various degree of success. They can be divided in several categories however, most of the machines introduced fall into one of the two typical structures: SIMD and MIMD. The first one, Single Instruction Multiple Data is characterized by executing one instruction at the time, operating on an array of data elements in parallel. A typical example of SIMD architecture is so called "Connection Machine" CM-1 introduced by Connection Machines of Cambridge Massachusetts in the first half of 1984. This machine is characterized by an array of up to 64K-processors divided in four quadrants containing 16K-processors each. CM-1 has been superseded by CM-2, 3 and CM-5. The operations of the processors are controlled by the same instruction issued from the central instruction unit. Another example of parallel SIMD architecture is the IBM GF-11 machine, capable of a peak execution rate of 11 billion floating-point operations per second. GF-11 was used to calculate the masses of the particles and would take 3 months to finish the calculation.

The current trend today is toward distributed computing on a large, even global, scale. This involves a network of workstations connected via high bandwidth, low latency networks acting as a computing platform. The goal is to take advantage of a large resource pool of workstations comprising of hundreds of gigabytes of memory, terrabytes of disk space and hundreds of gigaflops of processing power that is often being idle. This new paradigm in computing is expected to impact the fundamental design techniques for large systems and their ability to solve large problems, serve large number of users and provide a computing infrastructure.



Microphotograph of IBM PowerPC 620™, a 64-bit super-scalar processor containing 7 million transistors and capable of issuing four instructions in a single cycle built in 0.5μ CMOS technology. The processor has 32 Kbytes of instruction and data cache memory, and employs register renaming and branch prediction mechanisms. It runs at 100 MHz and achieves 250 SPEC integer and 300 SPEC floating point operations. (Photo by Tom Way and courtesy of IBM.)



500
100
50
10
5
Relative Integer Performance
21164
55%/yr
P6
21064
Pentium
"Snakes"
50%/yr
486
55%/yr
40%/yr
PA-RISC
R2000
386
86
87
88
89
90
91
92
93
94
95
Date of First Volume Shipments