MIPROC

A fast 16-bit microprocessor

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Abstract: The Norwegian Defense Research Establishment was an important innovator of new computers, software, technology, and instrumentation in 1960s and 1970s. One of the innovation projects was the MIPROC microprocessor. MIPROC had 16-bit architecture and a separated program memory to gain more speed. The control was based on a ROM to reduce the TTL chips numbers. The CPU had 75 instructions where each instruction executed in 250 ns. The technology was an important innovation by it self. The chips were implemented thin-film technology. By this technology, the data processor was reduced to four thin-film capsules.

Key words: Microprocessors, computer hardware, MIPROC

1. INTRODUCTION

In the period 1960 to 1980, the Norwegian Defense Research Establishment (NDRE) was an important innovator of computers, software, technology, and instrumentation. The most important project was the Penguin missile. This project forced the innovation of other smaller projects to solve instrumentation problems. One of these projects was the MIPROC microprocessor.

Analog electronics formed the basis for the electronics used in instrumentation. Analog electronics had fast signal processing, but at the same time, there were some basic limitations. Hard-wired analog electronics had no room for flexibility and the signal was influenced by noise and temperature drift. In this period, there was a paradigm shift from analog to digital electronics. Texas Instruments introduced the 74-series of TTL chips, National Semiconductor introduced the 3-state bus, and Intel introduced digital RAM and ROM. These digital chips opened the possibility of making programmable electronics for signal processing. Programmable electronics solved the fundamental problems of analog electronics. It opened the possibility of storing data in a memory. From stored data in a memory, it was possible to introduce a new generation of smart signal processing, smart control, and smart decisions.

The paradigm shift to digital programmable electronics opened a new set of challenges. Signal processing in real time needed a fast processor. The CPU architecture then had to be a simple design made for fast sequential operations. In 1970 computers still needed much space and the processor had to be reduces to a small card in a Penguin missile. Implementing the computer by thin film technology solved this problem. A third problem was the software needed for special dedicated computers. To solve the software problem, it was necessary to develop an assembler, a simulator, and a high-level language. The fourth problem was making a robust mechanic realization that was able to match military specifications.

The 16-bit MIPROC (MicroPROCessor) prototype was developed in 1972. The initial project group was Harald Schiøtz (project leader), Harald Yndestad, Sigurd Myklebust, and Ole Tormod Kristiansen. The LOGSIM CAD program tested the CPU design implemented on TTL chips. MIPROC had 16-bit architecture and separate program memory to increase the speed. Most of the control was ROM based to reduce the number of TTL chips. The CPU had 80 instructions where each instruction executed in 250 ns. The technology was an important innovation by it self. Thin-film technology implemented the CPU to reduce volume and weight.

A/S Infomasjonskontroll developed an assembler and a simulator in 1973. The following year, the Norwegian Computing Center at Blindern developed the high-level language PL/MIPROC. PL/MIPROC was an Algol-like programming language connected to the CPU registers. A/S Aker Electronics in Horten produced the MIPROC microprocessor for the Norwegian market and Plessey Microsystems in England produced it for the international marked.

2. THE MIPROC CPU ARCHITECTURE

The design of the MIPROC CPU architecture had three main targets. The first target was to implement a mini-computer instruction set which was able to handle signal processing. The second problem was developing as high speed as possible to handle fast signal processing. At the same time the power consumption had to be as low as possible.

The problem was solved by a simple 16-bit parallel CPU architecture. The CPU architecture had four basic units connected to a data bus and a control bus. This simple architecture made it possible to have simple, fast, and parallel operations. Figure 1 shows the simple 16-bit CPU architecture. The Arithmetic Unit had a 16-bit AC register and a 16-bit MQ register. Both registers connect to the 16-bit data bus. A 16-bit MAR register addresses the data memory. In this module, the RAM memory and the MAR address register connect to the CPU data bus. The control unit had a PC program counter, a RAM program memory, and a set of ROM. The ROM decoded the program code and produced the Control bus. We implemented a ROM feedback state machine to increase the multiplication speed. The In/Out unit had a control of the A/D-converters, the D/A-converters and digital in/out signals (Schiøtz, 1972; Yndestad, 1972; Schiøtz and Myklebust, 1976).

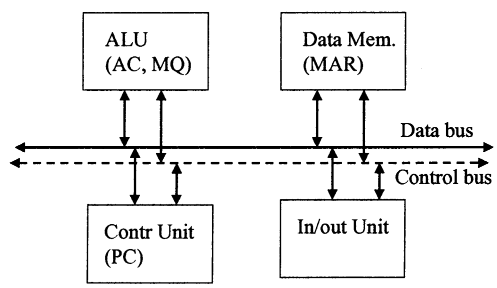

Figure 1. The MIPROC CPU Architecture.

Figure 2 shows the simple Arithmetic Unit. All logical and arithmetic operations executed in a 16-bit ALU (74181). Storage of the computed result was in the 16-bit accumulator register AC. The MQ register was a temporary register.

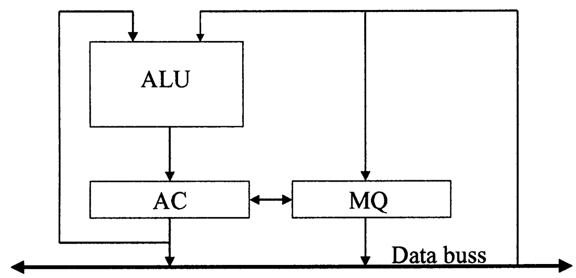

Figure 2. The Arithmetic Unit

The Arithmetic Control Unit (Figure 3) was the most complex part of the CPU. A 5 MHz oscillator clock was driving the 16-bit program counter (PC). The PC-state had a direct address control to the program memory. A set of ROM decoded the program memory code, which supported all control code to the common control bus. The CPU had separated program memory and data memory to gain speed. A separated program memory increased the speed 100%. All arithmetic operations were able to execute in a cycle time of 250 ns. A connection between the control code and the data Bus opened for a direct jump and set operations. The control unit had a micro controller to control multiplication, division, and conditional operations. The micro controller had a feedback control implementation between a register and a ROM. We designed this micro controller to gain fast multiplication and divisions. Table 1 shows the general specifications for the CPU.

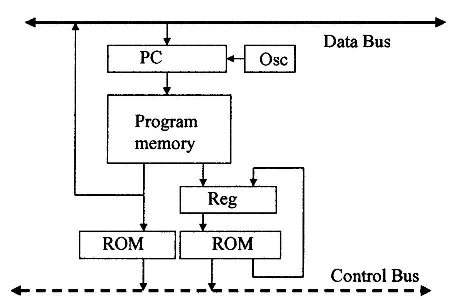

Figure 3. The Arithmetic Control Unit

Table 1: General specifications for the CPU

a) Word length	a) 16 bits
b) Maximum data memory	b) 64 K words
c) Maximum program memory	c) 64 K words
d) Maximum number inputs	d) 192
e) Maximum number outputs	e) 192
f) Basic execution time	f) 250 ns
g) Time for multiplication	g) 3.2-6.4 us
h) Time for division	h) 3.2-6.4 us
i) Number of instructions	i) 80
j) Direct data address	j) 256 words
k) Indirect data address	k) 64 K words
l) Dynamic address	l) 64 K words
m) Power supply	m) 5 v, 2 amp
n) Number TTL chips in the CPU	n) 18

3. THE MIPROC SOFTWARE

A/S Informationskontroll in Asker developed the basic MIPROC software for application development and software debugging in 1973. The MIPROC software had four main modules as shown in Figure 4. The MIPROC Assembler was the software package to transform the user software into the MIPROC instruction code. The BITSIM Simulator was a simulator of the MIPROC CPU architecture. The simulator was written in FORTRAN IV and the software was a model of the MIPROC CPU down to the bit level. This MIPROC model thus simulated all instructions and all basic CPU functions. The BITSIM Simulator linked to a WORLD Generator. The WORLD Generator was a simulation model of the external environmental that produced input signals to the MIPROC processor. The simulation model thus tested the application software on sampled real input data. USER Debug was a software package to debug application software. By special instructions in BITSIM Simulator the programmer was able to trace the state of the CPU in time periods (Risberg, 1973).

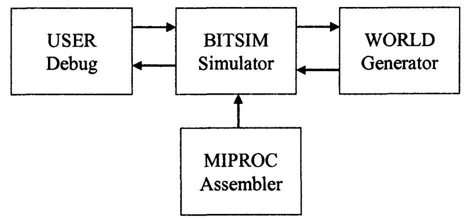

Figure 4. Simulator system

3.1 The PL/MIPROC language

The MIPROC microprocessor was designed for signal processing, which needs complex mathematical algorithms. To handle the complex algorithms, it was necessary to have a high-level language. At the same time, it was necessary to have real time control operations on the register level. The solution was an Algol-like pseudo high-level language to replace the assembly language.

PL/MIPROC was a programming language designed specifically for MIPROC. The language resembles Algol in structure, but contains data types and primitive operations, which allow the user full access to the basic functions of the MIPROC CPU. The basic structure in PL/MIPROC was the compound BEGIN...END, COMMENTS, the assignment A:=I+10, logic expressions as A:= B OR C; conditionals IF-THEN-ELSE and CASE IF; loop structures such as FOR-DO, WHILE-DO, REPEAT-UNTIL, functional PROCEDURES, and operation on memory arrays. The language was developed by Norwegian Computing Center in Oslo and was an important contribution to do programs readable, efficient and reliable (Wynn, 1974).

4. THE HARDWARE IMPLANTATION

We implemented and produced MIPROC in a thin-film version and as a standard TTL version. The thin-film version of MIPROC was for applications where volume and weight were the ultimate problem. A complete processor had four thin-film capsules on a custom-made card (Figure 5). The arithmetic unit and the data memory were implemented on a 5 x 5 cm capsule. This capsule was probably the biggest thin film capsule ever produced. The control unit and the I/O unit were implemented on a 2.5 x 5 cm capsule.

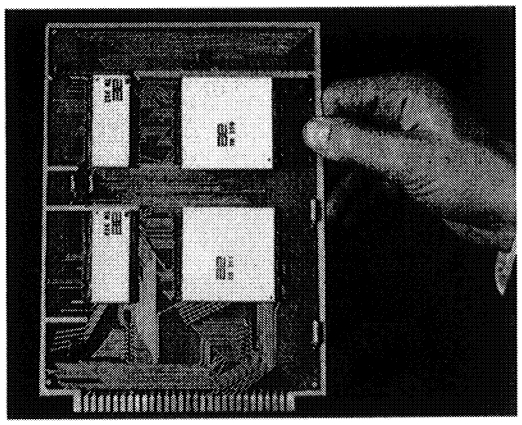

Figure 5. The MIPROC thin film version

Figure 6 shows the Standard MIPROC on a double Europe card. A Standard MIPROC was part of a number signal processing applications. Typical applications were Fast Fourier spectrum analysis, Kalman filters, and control applications. If one processor was too slow, additional processors were connected to increase the speed. NDRE at Kjeller developed the prototype and A/S Akers Electronics in Horten produced it.

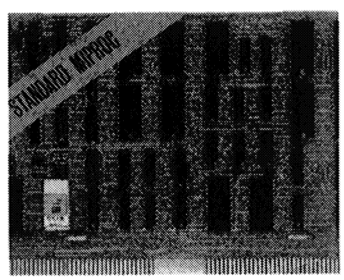

Figure 6. Standard MIPROC on a double Europe card

In 1974, the Norwegian Defense sold the international production rights to Plessey Microsystems in England for one million pounds. Plessey Microsystems constructed a factory in Towcester that employed about 300 people to produce the microprocessor, software, and specialized hardware applications. The processor was produced as a standard MIPROC. The most known specialized hardware was a Fast Fourier processor. Late at the 1980s, the MIPROC 16 was advertised in American journals under the headline "The fastest microcomputer known to man."

5. DISCUSSION

The simple parallel CPU architecture opened the possibility of making a simple, small, and powerful processor for fast signal processing in specialized instrumentation early at the 1970s. This opened the possibility of developing a new generation of electronic equipment. After the prototype period, we analyzed a new MIPROC concept to meet the next generation signal processing. This was a multi-processing systems and a processor based on ECL-technology (Yndestad, 1973; Yndestad, 1974).

The MIPROC microprocessor opened a possibility of a new export industry. In an early phase, industrial partners were interesting in producing MIPROC for the international marked. In this period, Intel and others were starting to make microprocessors with greater integration. It was clear that eventually this technology would be smaller, faster, cheaper, and more reliable. The result was that the production rights were sold to Plessey Microsystems in England and consequently never produced the next MIPROC generation. MIPROC made it possible to develop the first new generation of programmable electronics for signal processing in real time. The microprocessor thus contributed to a new generation of intelligent instrumentation before it was possible by the microprocessors from Intel and others. The new generation of digital instrumentation thus came earlier to the market. About five to ten years later, the more integrated microprocessors replaced the MIPROC.

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