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MIPROC

A fast 16-bit microprocessor

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Abstract. In 1960's and 1970's Norwegian Defense Research Establishment was an important innovator of new computers, software, technology and instrumentation. One of the innovation projects was the MIPROC microprocessor. MIPROC had a 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 was 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.

Introduction

In 1960's and 1970's 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 innovation of other smaller projects to solve instrumentation problems. One of these projects was the MIPROC microprocessor.

In 1970 most of the electronics in instrumentation were based on analog electronics. 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 influences 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, 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 a lot of 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 software. In those days software was made 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 Thormod Kristiansen. The CPU design was tested on the LOGSIM DAK program and then implemented by TTL chips. MIPROC had a 16-bit architecture and separate program memory to increase the speed. Most of the control was based on a ROM to reduce the number of TTL chips. The CPU had 80 instructions where each instruction was executed in 250 ns. The technology was an important innovation by it self. The CPU was implemented by thin-film technology to reduce volume and weight.

In 1973 A/S Infomasjonskontroll developed an assembler and simulator. Next 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. The MIPROC microprocessor was produced by A/S Akers Electronics in Horten for the Norwegian marked and by Plessey Microsystems in England for the international marked.

The MIPROC CPU architecture

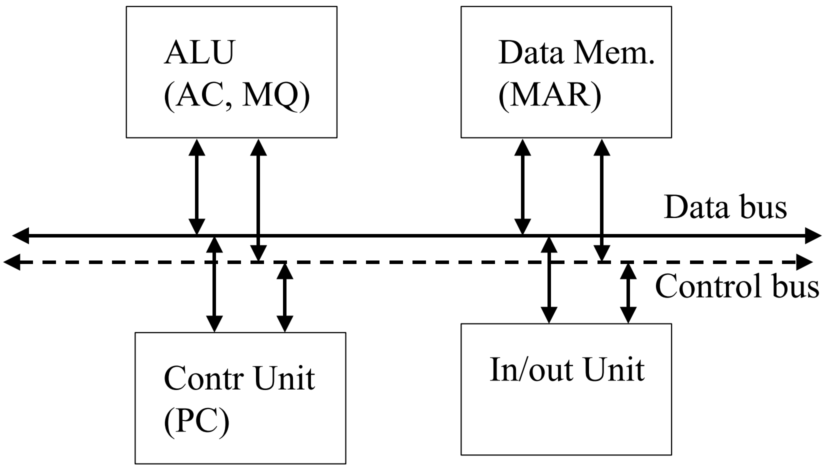

Figure 1. The MIPROC CPU architecture.

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 to develop 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 4 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 were connected to the 16-bit data bus. The Data memory was addressed by a 16 bit MAR register. In this module the RAM memory and the MAR address register were connected 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. A ROM feedback state machine was implemented to increase the multiplication speed. The In/Out Unit had a control of the A/D-converters, the D/A-converters and digital inn/out signals (Schiøtz, 1972; Yndestad, 1972; Schiøtz and Myklebust, 1976).

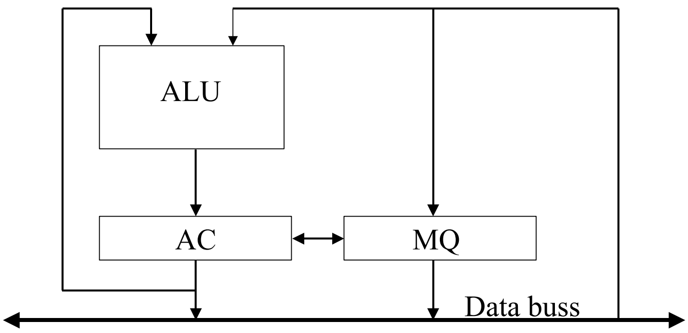

Figure 2. The Arithmetic Unit.

Figure 2 show the simple Arithmetic Unit. All logical and arithmetic operations were executed in a 16-bit ALU (74181). The computed result was stored in the 16-bit accumulator register AC. The MQ register was used as a temporary register.

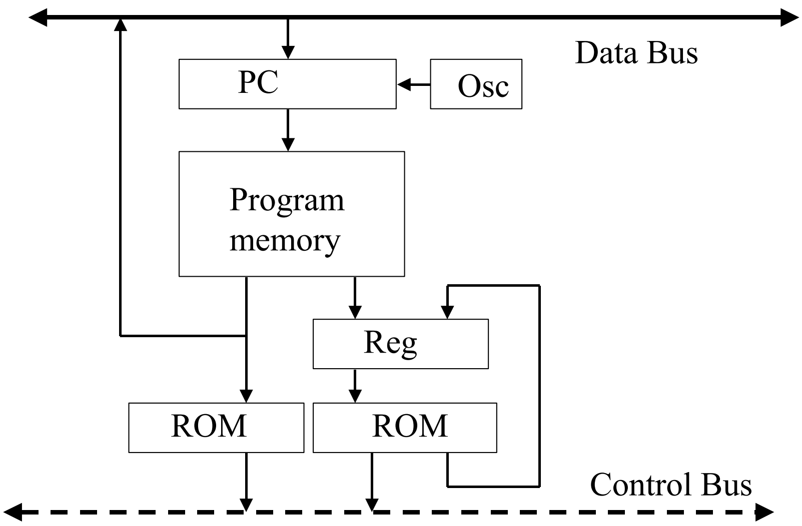

Figure 3. The Arithmetic Control Unit.

The Arithmetic Control Unit was the most complex part of the CPU. A 5 MHz oscillator clock was diving the 16-bit Program counter (PC). The PC-state had a direct address control to the Program memory. The Program memory code was decoded in a set of ROM, 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 executed in a cycle time of 250 ns. A connection between the Control code and the Data Bus opened for direct jump and set operations. The

Control Unit had a micro controller to control multiplications, divisions and conditional operations. The micro controller was implemented by a feedback control between a register and a ROM. This micro controller was designed to gain fast multiplications and divisions.

General specifications

The CPU had the following general specifications:

Word length	16 bits
Maximum data memory	64 K words
Maximum program memory	64 K words
Maximum number inputs	192
Maximum number outputs	192
Basic execution time	250 ns
Time for multiplication	3.2-6.4 us
Time for division	3.2-6.4 us
Number of instructions	75
Direct data address	256 words
Indirect data address	64 K words
Dynamic address	64 K words
Power supply	5 v, 2 amp
Number TTL chips in the CPU	18

The MIPROC software

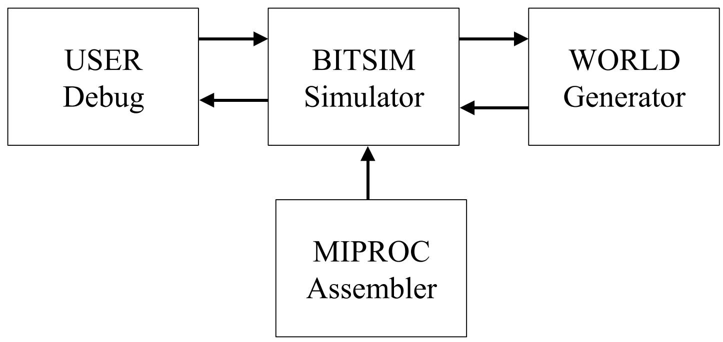

Figure 4. Simulator system

In 1973 A/S Informationkontroll in Asker developed the basic MIPROC software for application development and software debugging. The MIPROC software had 4 main modules. 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 was linked to 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 real sampled 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).

PL/MIPROC

The MIPROC microprocessor was designed for signal processing which needs complex mathematic 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 primitives operations, which allow the user full access to the basic functions of the MIPROC CPU. The basic structure in PL/MIPROC was Compound BEGIN…END, COMMENTS, Assignment A:=I+10, LOGIC A:= B OR C; IF THEN ELSE, CASE IF; FOR DO, WHILE DO, REPEAT UNTIL PROCEDURES and operation on memory arrays. The language was developed by Norwegian Computing Center in Oslo and was an important contribution to make the programs readable, efficient and reliable (Wynn, 1974).

The hardware implantation

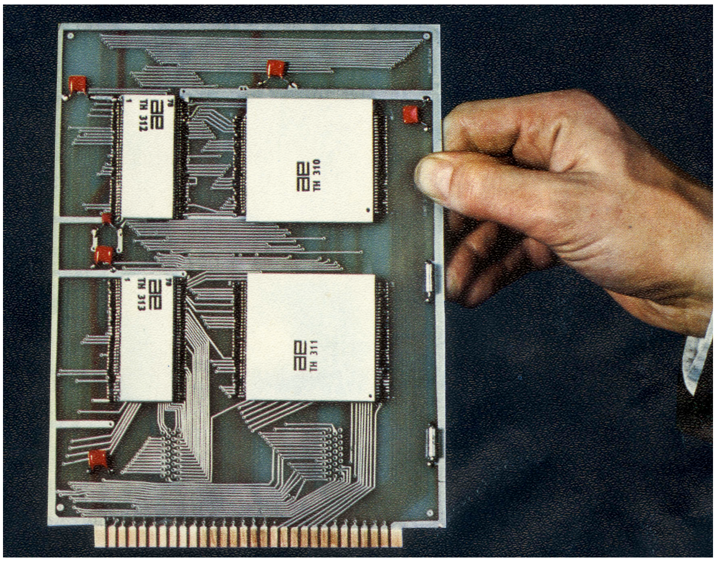

Figure 5. The MIPROC thin film version

MIPROC was implemented and produced in a thin-film version and as a standard TTL version. The thin-film version of MIPROC was made for applications where volume and weight was 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 was implemented on a 2.5 x 5 cm capsule.

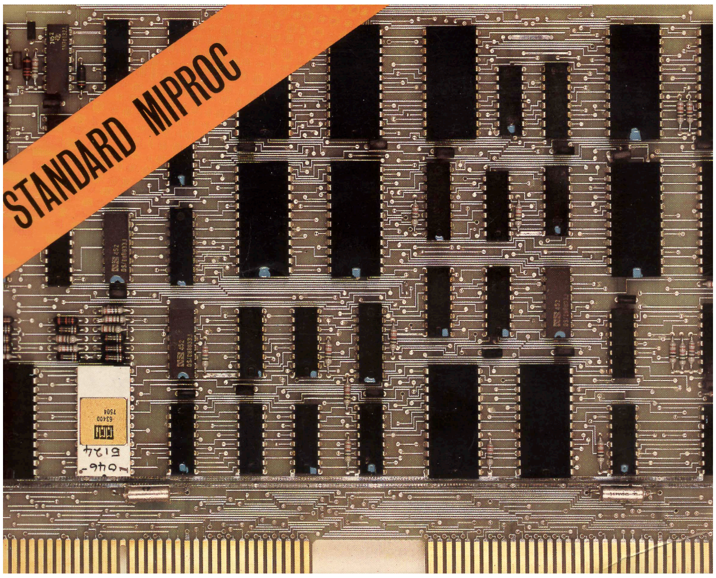

Figure 6. Standard MIPROC on a double Europe card

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

In 1974 the Norwegian Defense sold the international production rights to Plessey Microsystems in England for 1 million pounds. Plessey Microsystems made a factory in Towcester where about 300 people was employed to produce the microprocessor, software and specialized hardware applications. The most known specialized hardware was a Fast Fourier processor. As late as in the 1980' MIPROC 16 was advertised in American journals under the headline "The fastest microcomputer known to man".

Discussion

The simple parallel CPU architecture opened the possibility to make a simple, small and powerful processor for fast signal processing in specialized instrumentation early in the 1970's. This opened the possibility to develop a new generation of electronic equipment. After the prototype period a new MIPROC concepts was analyzed to meet a 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. But in this period Intel and others was starting to make more integrated microprocessors. It was clear that sooner or later 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 a next MIPROC generation was never produced. 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 marked. About 5 to 10 years later MIPROC was replaced by the more integrated microprocessors.

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