REAL-TIME MICROCOMPUTING: THE FIRST SEVEN DECADES

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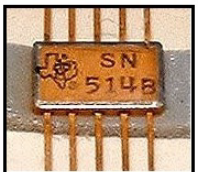
Abstract:

Seven decades of the continuous development and improvement of the computing infrastructure (hardware, software and firmware) played a crucial role in a parallel development of many other compatible disciplines, including Artificial Intelligence. The computing paradigm changed dramatically upon introduction of integrated microprocessors, resulting even in corresponding terminological changes – by introducing new more appropriate terms like microcomputer and microcomputing. This article is a historical overview of this topic, through the brief presentation of the long-time lasting project ATLAS, which is still successfully running in the Institute Mihailo Pupin in Belgrade, Serbia. The article is specially focused to the period when the integrated microprocessor INTEL 8080 entered into the computing arena.

Keywords: ATLAS, microprocessor, microcomputer, microcomputing, development system, real-time, ICE emulator

1. Introduction

First **integrated circuit** was introduced in **1960/61.** US companies **Fairchild Semiconductor** and **Texas Instruments**, two leading manufacturers of electronics components, independently succeeded in integrating a certain number of transistors and other active and passive electronics elements into a single functional unit and packed them together in a common small-size package (Fig. 1). Something that previously was a printed circuit board (PCB) suddenly became a single small unit with multiple input/output pins, ready to be connected with other components to build more complex devices[1]. Additionally, such an IC had much better characteristics and performances than its functional ancestor – its parasitic resistance, inductivity and capacity were significantly decreased causing also lower power consumption.



First integrated circuit
(Texas Instruments)

Fig.1

[1] The presented IC SN514B is a NOR/NAND logic gate. Its initial price was cca. $400, and this IC "flied" in the space in 1963.

Furthermore, on-going technology development led to the large scale integration procedures[2] and manufacturing of LSI (large scale integration) and VLSI (very large scale integration) integrated circuits (Fig. 2). An impact to the further electronic designing was enormous – digital approach became more feasible and attractive to future designers[3].

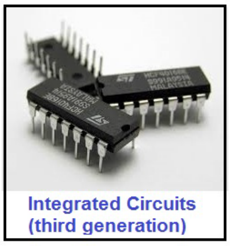


Fig. 2

In the year of **1971** relatively new company **INTEL**[4] put on the market first integrated 4-bit microprocessor **Intel 4004**, and in the very next year of **1972** the first integrated 8-bit microprocessor **Intel 8008**. Although both microprocessor have not been widely accepted and implemented, they are important because they definitely represented breakthrough in the IC manufacturing – they "paved the roads" for future generations of better microprocessors. There were rumors at that time that INTEL even "invented" a microprocessor to increase a sale of its principal product: memories, because each microprocessor is requiring larger number of memory chips.

First integrated microprocessor that behaved as a real computer processor unit was the 8-bit microprocessor **Intel 8080** that was introduced in April of 1974 (Fig. 3). It was a real breakthrough in "a storming digital revolution" and it was greatly accepted in professional circles [3]. It is worth to know that computers were huge in size and extremely expensive at that time – so an introduction of a small and cheap integrated microprocessor made (something previously unimaginable): an easier designing of other software-driven digital electronics devices.

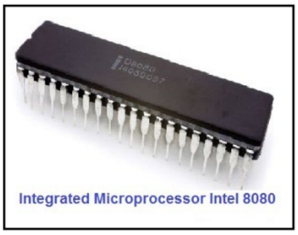


Fig. 3

Soon, other manufacturers also followed – the very same year **Motorola** introduced its 8-bit integrated microprocessor **MC6800**, a mate product of similar characteristics (Fig. 4). Not long later, as a result of joined development of **INTEL** and **ZILOG**, the new integrated microprocessor **Z-80** appeared.

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[2] Techology development led to a successful integration of larger number of transistors (soon counting in thousands), with an increased releability of ICs at the same time.

[3] Digital electronic designing was already spread before an introduction of integrated circuits. Digital computers realized in transistor technology (and even with electronic tubes) existed and were in use.

[4] Development of the first integrated microprocessor was led by the same group of researchers that inventrd first integrated circuits. Few leading researchers from Fairchild Semiconductor left company in 1968 and founded the new company INTEL (Integrated Electronics) – nowadays the well-known giant in the area of development and manufacturing of microprocessors and other electronics components.

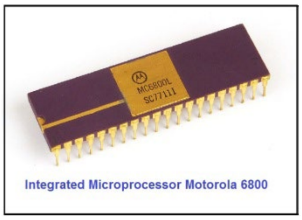


Fig. 4

2. ATLAS – Microcomputer Control System

ATLAS is a standard name for all generations of systems for remote and local monitoring and control, developed and manufactured in the Belgrade's Institute Mihailo Pupin for more than half a century. ATLAS system primary mission is its implementation in geographically distributed utility control systems: like electrical power systems, water-supply systems, irrigation systems, gas distribution systems, etc. A development of an ATLAS system mostly targeted electrical power utilities, because of their high-demanding operational and environmental requirements. Briefly, if an ATLAS system could successfully "swim" in electro-power "pools", it would be definitely well-suited for any other environment too.

Since its foundation, Institute Mihailo Pupin was, and still is, among leading science-research institutions in the country in applied electronics, automatics, communication and computer engineering. Same was in 70-ties of the last century. Open toward innovations, with competent and knowledgeable staff, Institute Mihailo Pupin was always an incubator of knowledge and new ideas. Circulation of professional magazines, papers, catalogues, advertising stuff and others[5], gave a chance to professionals to catch-up global trends and development. New technologies have been quickly accepted and implemented locally. – including a microprocessor appearance. So, in the summer of 1974, the brief brochure "**From CPU to Software**" (Fig. 5), which announced a new INTEL microprocessor[6] 8080 reached our shores. A new era in computer designs started.

Fig.5

However, the very first step at that time was *how to deal with a new challenging technology* – especially how to make a choice between available competing functionally similar products: **Intel 8080** and **Motorola 6800** microprocessors. Motorola was already well-known and reliable manufacturer, and designing with its microprocessor 6800 seemed to be easier… However, upon an overall product evaluation, the final decision pointed to **Intel 8080**, especially because INTEL introduced a commercially available stand-alone

[5] There was no internet at that time, and well-supplied Institute's Library played a very important role.
[6] Unfortunately, a brief description hided many needed details for full understanding

development system (basically, a stand-alone computer – Fig. 6), which made possible to build a development environment at any place, in the user's lab or office, without being directly dependent of the manufacturer itself, or other resources that we could not approach at that time[7].

Development System Intellec MDS-80

Fig. 6

Many years later, when Intel's microprocessors of third, fourth and fifth generation played a main role in manufacturing of personal computers (PCs), it became obvious how that decision was smart.

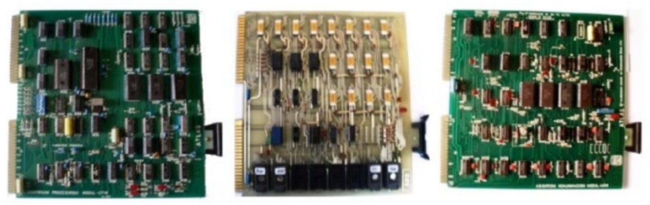
So, in the **early autumn of 1975**, the first integrated microprocessor Intel 8080 and a certain number of supporting ICs arrived in Institute Mihailo Pupin. This set of components was carefully selected and ordered for a project of a "dedicated microcomputer", which will be the core for a design of a software-driven Remote Terminal Unit (RTU) and Central Control Unit of a new microcomputer-based ATLAS Remote Control System[8] [3].

2.1 Hardware

Hardware design started even earlier, but since arrival of components and supporting documentation (especially for the Development System MDS-80) the real evaluation of the whole project feasibility could be fully done. Project included two parts: a hardware design of the microcomputer-driven Central Control Unit (CCU) and designing of larger number of Process Interface Modules controlled by CCU [1,3]. Of course, main focus was on CCU part.

Crucial CCU modules (printed circuit boards - PCBs), which made a microcomputer, were designed[9] (Fig. 7):

- Microprocessor CPU module with a nested interrupt logic and watch-dog timer - WDT
- Memory module of 2KB RAM and 2KB EPROM
- Communication module (4 asynchronous serial channels)



Central Control Unit: Processor, Memory and Communication Modules

Fig. 7

[7] At the beginning, a development of needed programs was able only through large commercial computer networks like CompuServe and similar, the ones that we could not approach at all.
[8] Most probably it was the very first integrated microprocessor implementation in that-day Yugoslavia.
[9] It is worth to have in mind that the project of hardware design included larger number of process interface modules, which are not presented in this review.

An odd curiosity was a choice of Motorola's IC ACIA 6850, from a set of supporting components for microprocessor 6800 (ACIA stands for: asynchronous communication interface adapter) in the design of 4-channel Communication Module. Simply, ACIA 6850 fits better than a corresponding INTEL's IC – although it made its connection with Intel 8080 microprocessor more complex.

Few years later, another powerful **Microcomputer Module** named **MRM** was designed (Fig. 8). MRM was a functional replacement for three presented CCU modules [7]. Although its functions were slightly reduced and with lower performances, MRM was ideal for realization of smaller systems and devices – what exactly was a purpose of its design.

Fig. 8

2.2 Software

The next project step was a real-time software design. The designed hardware had a number of restrictions, especially related to the program execution speed and available memory space to store needed programs and data. There was no any available operating system – OS, which would make overall program organization and implementation easier. The only clear issue from the very beginning was the fact that the only available language to make software was **assembler**, which is not "user-friendly". However, assembler is close to hardware and allows its efficient and economical control. A platform for program editing and assembling was the existing MDS development system. But a real challenge was program debugging – how to be sure that a written and assembled program (translated into machine code that microprocessor understands and executes) would work properly once it is transferred into EPROM (erasable programmable read-only memory) of the designed hardware. How to figure-out between software bug and hardware failure?

Fortunately, INTEL headed with a solution – soon a powerful tool ICE emulator (In Circuit Emulator) appeared on the market (Fig. 9). It was a special hardware unit that enabled an efficient connection of the MDS development system and a designed hardware – simply, by replacing microprocessor[10] with ICE emulator. In that way, an "inside view" to the designed system was enabled[11]. All available MDS resources were now dedicated to microprocessor emulation and "comfortable" software and hardware debugging [8].

Fig. 9

[10] Microprocessor should be unplugged from its socket and ICE emulator cable plugged instead.
[11] ICE emulator was even advertised as "umbilical cord" between MDS development system and designed user's hardware.

Finally, which real-time OS to choose? It was easy, none was available. So, the logical choice was a home-made solution [2,5,6], presented in Fig. 10.

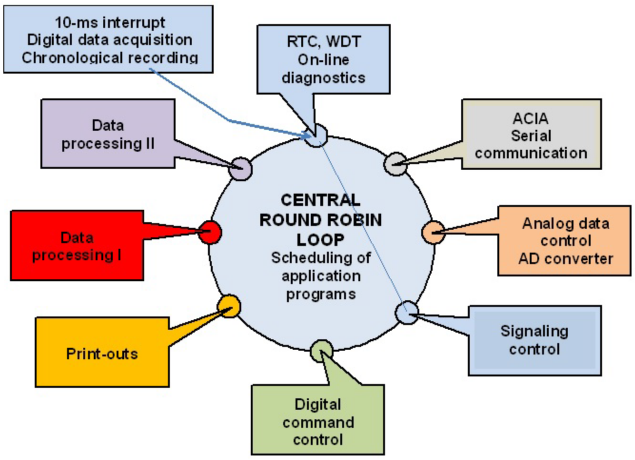


Fig 10

- Central round-robin distributor with connected points for application programs and WDT control (watch-dog timer).
- 10-ms high-priority interrupt program controls RTC (real-time clock) and enables real-time program execution and remote communication.
- Application data acquisition and data delivery programs control process interface hardware.
- Application data processing programs, program for printing, etc.
- On-line diagnostics programs.

2.3 Project Realization

In the year of 1976/77 two prototypes were completed: the Remote Control Unit named **ATLAS-SST** and the Central Control Unit named **ATLAS-CST**. Complete hardware and real-time software were purposely designed and debugged, two units connected and fully tested. After all job done, "two meters" of printed program listings remained behind, as well as many sleepless nights. The project was successfully finished[12] - new orders followed. How it looked like in the institute's "digital workshop" could be seen in the picture (Fig 11):

[12] The project was financed by the Belgrade's Utility Company EDB – Elektrodistribucija Beograd,

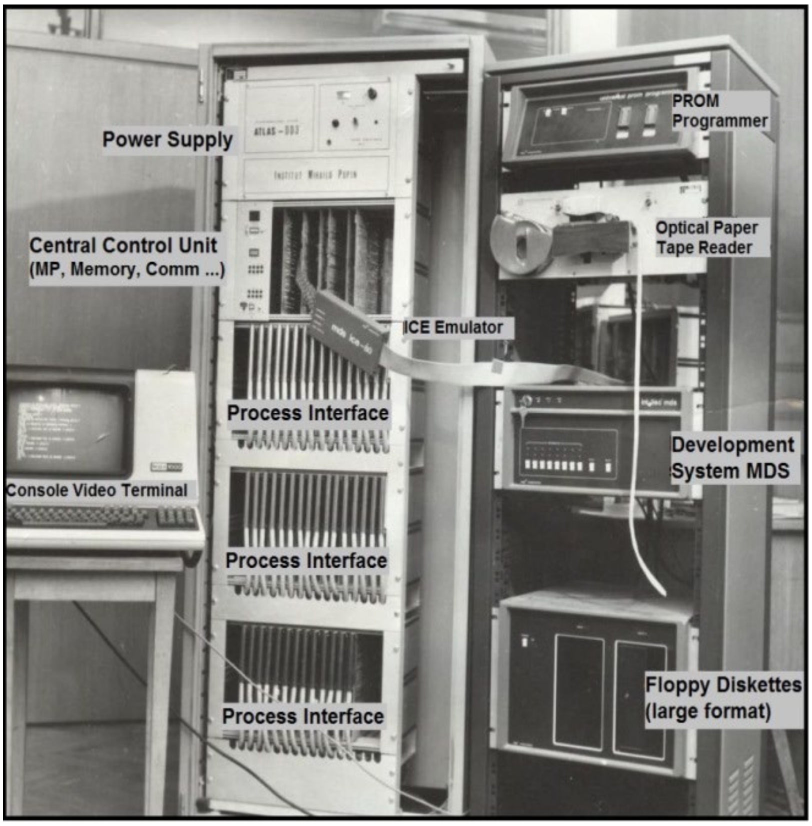


Fig. 11

One “important player” is missing from the picture. This is a printer – an intensive printing of written programs was crucial for software development and program debugging. In the first phase, it was **Teletype ASR-33** (Fig. 12) with mechanical 10 character/sec paper tape reader and punch, which was used until its “breakdown”. Later it was replaced with another serial printer. At the very beginning of the project, ASR-33 was the only peripheral device connected to the MDS development system, used as a system console, an input device (its keyboard and paper tape reader) and an output device (print-out and data archiving via paper tape punch).

Fig. 12

The picture in Fig 11 was made in the **year 1978** and shows a final testing phase of the chronological event recording system **ATLAS DD3**, build for needs of Electrical Power Industry of Serbia [4,6].

2.4 Further Development - Next System Generations

A significant number of this generation microcomputer systems was made in Institute Mihailo Pupin and delivered to different profile customers[13]. Systems were in operation for many years in different environmental and operational conditions[14]. At the same time, the accumulated knowledge and experience made a solid ground for further developments of complement products, like: SCADA - Supervisory Control and Data Acquisition Systems, new generations of Remote Control Systems and ATLAS PLC - Programmable Logic Controlers, as well as many other supporting hardware and software components (Ladder Diagrams, system setup utilities, etc.).

In 1980-ties personal computers (better known by the nickname PC) became market available[15]. The intensive development that followed caused the switch of the ATLAS project toward market available microcomputer products, while a focus remained to the required process interface (hardware-wise) and needed real-time system and application software and firmware. The decision was fully implemented in 1988 with the choice of a 32-bit PC-AT MSDOS compatible microcomputer and real-time VRTX OS, and soon a new ATLAS generation was put in operation [9].

The new millennium brought a new generation of ATLAS-MAX/RTL systems based on embedded microcomputer hardware and real-time LINUX OS. Such an approach enabled higher levels of a system flexibility, reliability, TCP/IP communication and processing distribution. Especially, possibility for redundant configurations played important role in the increased ATLAS system availability (Fig 13). Furthermore, system extensions to other supported microcomputer peripherals carried-out with additional benefits.

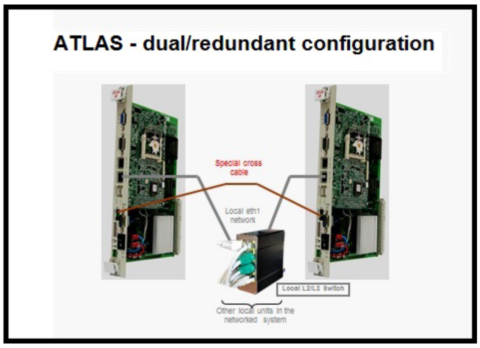


Fig 13

For less demanding control systems, when a large powerful microcomputer implementation could be too expensive, smaller microprocessor based ATLAS devices were developed. The project **pikoAtlas** is such an example (Fig. 14). The prefix "*piko*" in its name points to small physical dimensions of the unit, while to describe its processing capabilities more appropriate prefix would be "*mega*".

[13] Device programmability allows its easy customization to the real user's need – the very same hardware could execute very different jobs.

[14] Some of this generation systems are still in operation, after 40 years of continuous exploitation.

[15] The first real personal computer IBM PC-XT (with 8-bit architecture) was launched in the year 1983. Soon it was replaced by a better 16-bits PC-AT and ISA system bus. In the years 1986/87 a 32-bits PCs are market-dominant (Intel 80386 and clones with PCI system bus). In the next decade, 64-bits PCs (Intel Pentium and similar microprocessors) became commodities.

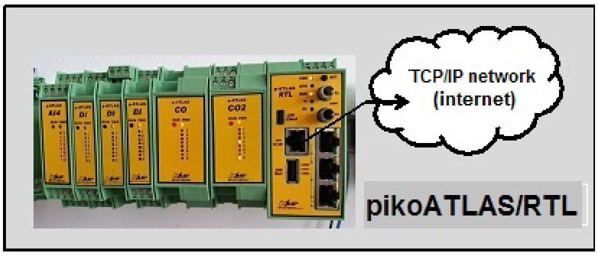


Fig. 14

For situations when even *pikoATLAS* could be inappropriate, there is a set of several small-size ATLAS devices of the fifth generation (Fig. 15). Having in mind their network capabilities to build larger distributed processing systems, we can say that all system variations are fully covered.

Fig 15

3. Conclusion

It is hard to imagine AI (artificial intelligence) implementation out of an intensive computing environment. Since the appearance of integrated microprocessor 50 years ago, the computing environment significantly changed, as well as a human environment in general. A fast development of processing equipment, with continuous performance improvements (doubled speed and processing power almost every two/three years) offered unimaginable opportunities for parallel development and implementation of many applications around us, including the real-time AI applications.

This article is an attempt to historically present the available computing environment through an overview of the project ATLAS, which is going-on for more than five decades in the Institute Mihailo Pupin in Belgrade, Serbia. In certain details it is an extended version of an earlier author's presentation on a similar topic [10]. The used terminology refers to microcomputers and microcomputing, which actually describes the computing environment in more appropriate way since the introduction of integrated microprocessors in 1970-ties. To fulfill a gap between quoted seven decades in the title of the article, and five decades of a real microcomputing, it is worth to refer to another project in the Institute Mihailo Pupin accomplished in the 1960-ties. This was the project **CER** – the acronym for "*Cifarski Elektronski Računar*", or translated in English "*Digital Electronic Computer*". The realized computers were used for many years locally for data processing purposes. The accumulated knowledge and experience in this project contributed in many aspects to the successful start of the later project ATLAS.

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