GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA
FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2025

THIRD INTERNATIONAL CONFERENCE
24-25 SEPTEMBER, 2025

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

УНИВЕРЗИТЕТ „ГОЦЕ ДЕЛЧЕВ“, ШТИП
ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ

GOCE DELCEV UNIVERSITY, STIP
FACULTY OF ELECTRICAL ENGINEERING

ТРЕТА МЕЃУНАРОДНА КОНФЕРЕНЦИЈА
THIRD INTERNATIONAL CONFERENCE

ЕТИМА / ETIMA 2025

ЗБОРНИК НА ТРУДОВИ
CONFERENCE PROCEEDINGS

24-25 септември 2025 | 24-25 September 2025

ISBN: 978-608-277-128-1
DOI: https://www.doi.org/10.46763/ETIMA2531

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Издавач / Publisher
Универзитет „Гоце Делчев”, Штип / Goce Delcev University, Stip
Електротехнички факултет / Faculty of Electrical Engineering

Адреса на организационен комитет / Adress of the organizational committee
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Адреса: ул. „Крсте Мисирков“ бр. 10А / Adress: Krste Misirkov, 10A
Пош. фах 201, Штип - 2000, С. Македонија / PO BOX 201, Stip 2000, North Macedonia
E-mail: conf.etf@ugd.edu.mk

CIP - Каталогизација во публикација
Национална и универзитетска библиотека "Св. Климент Охридски", Скопје

62-049.8(062)
004-049.8(062)

МЕЃУНАРОДНА конференција ЕТИМА (3 ; 2025 ; Штип)
Зборник на трудови [Електронски извор] / Трета меѓународна конференција ЕТИМА 2025, 24-25 септември 2025 ; [главен и одговорен уредник Сашо Гелев] = Conference proceedings / Third international conference, 24-25 September 2025 ; [editor in chief Saso Gelev]. - Текст во PDF формат, содржи 357 стр., илустр. - Штип : Универзитет "Гоце Делчев", Електротехнички факултет ; Stip : "Goce Delchev" University, Faculty of Electrical engineering, 2025

Начин на пристапување (URL): https://js.ugd.edu.mk/index.php/etima/en. - Наслов преземен од екранот. - Опис на изворот на ден 30.10.2025. - Трудови на мак. и англ. јазик. - Библиографија кон трудовите

ISBN 978-608-277-128-1

а) Електротехника -- Примена -- Собири б) Машинство -- Примена -- Собири
в) Автоматика -- Примена -- Собири г) Инфоматика -- Примена -- Собири

COBISS.MK-ID 67297029

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PREFACE

The Third International Conference “Electrical Engineering, Technology, Informatics, Mechanical Engineering and Automation – Technical Sciences in the Service of the Economy, Education and Industry” (ETIMA’25), organized by the Faculty of Electrical Engineering at the “Goce Delchev” University – Shtip, represents a significant scientific event that enables interdisciplinary exchange of knowledge and experience among researchers, professors, and experts in the field of technical sciences. The conference was held in an online format and brought together 78 authors from five different countries.

The ETIMA conference aims to establish a forum for scientific communication, encouraging multidisciplinary collaboration and promoting technological innovations with direct impact on modern life. Through the presentation of scientific papers, participants shared the results of their research and development activities, contributing to the advancement of knowledge and practice in relevant fields.
The first ETIMA conference was organized four years ago, featuring 40 scientific papers. The second conference took place in 2023 and included over 30 papers. ETIMA’25 continued this scientific tradition, presenting more than 40 papers that reflect the latest achievements in electrical engineering, technology, informatics, mechanical engineering, and automation.

At ETIMA’25, papers were presented that addressed current topics in technical sciences, with particular emphasis on their application in industry, education, and the economy. The conference facilitated fruitful discussions among participants, encouraging new ideas and initiatives for future research and projects.

ETIMA’25 reaffirmed its role as an important platform for scientific exchange and international cooperation. The organizing committee extends sincere gratitude to all participants for their contribution to the successful realization of the conference and its scientific value.

We extend our sincerest gratitude to all colleagues who, through the presentation of their papers, ideas, and active engagement in discussions, contributed to the success and scientific significance of ETIMA’25.

The Organizing Committee of the Conference

ПРЕДГОВОР

Третата меѓународна конференција „Електротехника, Технологија, Информатика, Машинство и Автоматика – технички науки во служба на економијата, образованието и индустријата“ (ЕТИМА’25), организирана од Електротехничкиот факултет при Универзитетот „Гоце Делчев“ – Штип, претставува значаен научен настан кој овозможува интердисциплинарна размена на знаења и искуства меѓу истражувачи, професори и експерти од техничките науки. Конференцијата се одржа во онлајн формат и обедини 78 автори од пет различни земји.

Конференцијата ЕТИМА има за цел да создаде форум за научна комуникација, поттикнувајќи мултидисциплинарна соработка и промовирајќи технолошки иновации со директно влијание врз современото живеење. Преку презентација на научни трудови, учесниците ги споделуваат резултатите од своите истражувања и развојни активности, придонесувајќи кон унапредување на знаењето и практиката во релевантните области.

Првата конференција ЕТИМА беше организирана пред четири години, при што беа презентирани 40 научни трудови. Втората конференција се одржа во 2023 година и вклучи над 30 трудови. ЕТИМА’25 продолжи со истата научна традиција, презентирајќи повеќе од 40 трудови кои ги отсликуваат најновите достигнувања во областа на електротехниката, технологијата, информатиката, машинството и автоматиката.

На ЕТИМА’25 беа презентирани трудови кои обработуваат актуелни теми од техничките науки, со посебен акцент на нивната примена во индустријата, образованието и економијата. Конференцијата овозможи плодна дискусија меѓу учесниците, поттикнувајќи нови идеи и иницијативи за идни истражувања и проекти.

ЕТИМА’25 ја потврди својата улога како значајна платформа за научна размена и интернационална соработка. Организациониот одбор упатува искрена благодарност до сите учесници за нивниот придонес кон успешната реализација на конференцијата и нејзината научна вредност. Конференцијата се одржа онлајн и обедини седумдесет и осум автори од пет различни земји.

Изразуваме голема благодарност до сите колеги кои со презентирање на своите трудови, идеи и активна вклученост во дискусиите придонесоа за успехот на ЕТИМА’25 и нејзината научна вредност.

Организационен одбор на конференцијата

СОДРЖИНА / TABLE OF CONTENTS:

Трета меѓународна конференција ЕТИМА
Third International Conference ETIMA
UDC: 004.272.22.05
https://www.doi.org/10.46763/ETIMA2531123g

BENEFITS OF STUDYING 8086 MICROPROCESSOR FOR UNDERSTANDING CONTEMPORARY MICROPROCESSOR

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Abstract

This paper explores the benefits of studying the 8086 microprocessor to enhance the understanding of contemporary microprocessors. The 8086 microprocessor, introduced by Intel, is a foundational architecture that paved the way for modern microprocessor designs. By analyzing its core components and instruction set, we demonstrate how fundamental concepts introduced in the 8086 are still relevant in today's advanced processors. The paper compares the architectural evolution of microprocessors, highlighting key differences and similarities between the 8086 and modern processors.
A comparative analysis underscores the value of studying the 8086, particularly for students and professionals seeking to deepen their knowledge of microprocessor architecture. We emphasize how understanding this early processor facilitates learning more complex features found in contemporary systems.
In the experimental section, results from tests performed using the 8086 Emulator and DevC++ are presented. These experiments evaluate how basic operations and instructions from the 8086 are executed and compared with similar operations in contemporary compilers. This evaluation confirms the continuing relevance of foundational microprocessor principles and their role in modern technological advancements.

Key words

8086 microprocessor, pipelining, contemporary microprocessor, Emu8086

Introduction

Intel Corporation first introduced the term "microprocessor." A microprocessor is made up of an arithmetic and logic unit, a register unit, and a control unit. These three units are integrated into a single chip. Microprocessors are generally classified by their speed, word length, architecture, and instruction set. Today, 8-bit, 16-bit, and even 32-bit microprocessors are highly advanced. Several independent microprocessor families are available on the market. These microprocessors are widely used in the design of new electronic devices and computers. [1].
We all know that the 8086 microprocessor played a pivotal role in the development of microprocessors, shaping the future of computing. The 8086 is a slightly modified chip, the first 16-bit microprocessor, with 20 address lines and 16 data lines, providing access to up to 1MB of memory. This chip gave rise to the x86 architecture.
The Intel 8086 microprocessor was developed to significantly boost processing performance compared to the older 8080 model. One of its key design objectives was to maintain compatibility with the 8080 at the assembly language level, ensuring that existing 8080 software could be reassembled and executed correctly on the 8086. To achieve this, the register set and instruction set of the 8080 were incorporated as logical subsets within the 8086. The design of

the 8086 aimed to symmetrically extend the features of the 8080 while also introducing new processing capabilities that were not available in the 8080. [2].

The architecture of the 8086 microprocessor is based on a complex instruction set computer (CISC) architecture, which supports a wide range of instructions, many of which can perform multiple operations in a single instruction. Additionally, the 8086 features a segmented memory architecture, meaning that memory is divided into segments addressed using both a segment register and an offset. The segment register points to the start of a segment, while the offset specifies the location of a specific byte within the segment. One advantage of this design is that it allows the 8086 microprocessor to access large amounts of memory, even with a 16-bit data bus.

The 8086 was famously used in the first IBM PC, an association that solidified its place in computing history. However, despite its many advantages, the 8086 was originally introduced by Intel in 1978 and is unable to keep up with the rapid technological advancements of today. This raises the question: What are the benefits of studying the 8086 microprocessor?

Although the 8086 is an older model, its architecture laid the foundation for many concepts still in use today, such as instructions, registers, and addressing modes. By learning the basic principles from the 8086, students and engineers can gain a better understanding of modern designs, optimizations, and the complex systems used in today's processors. Ultimately, knowledge of these foundational concepts facilitates an easier transition to working with new technologies and advanced architectures.

1. 8086 Microprocessor

In 1978, Intel introduced the 8086 microprocessor, which marked a significant milestone in the industry. Developed in just 18 months, the 8086 revolutionized computing due to its ability to support more complex and versatile applications compared to its predecessors. Its architecture became the blueprint for future processors, and it was Intel's first microprocessor to incorporate microcode.

Additionally, Intel created a comprehensive range of supporting products and development tools, enabling clients to maximize the potential of the processor in their implementations. 8086 microprocessor does not contain internal RAM or ROM. However, it features internal registers that store intermediate and final results, and it communicates with external memory via the System Bus. The 8086 is a 16-bit integer processor housed in a 40-pin Dual Inline Package (DIP).

As an integrated circuit that functions as a CPU, a microprocessor can not operate independently. Unlike a microcontroller, it lacks built-in memory and peripherals, necessitating the use of external components for full system functionality.

The 8086 microprocessor features an extensive set of registers, including general-purpose registers, segment registers, and special registers. The general-purpose registers are utilized for data storage and performing arithmetic and logical operations, while the segment registers handle memory segment addressing. Among the special registers are the flags register, which stores status information about the outcome of the previous operation, and the instruction pointer (IP), which indicates the address of the next instruction to be executed.The size of the internal registers, which in this case are 16-bit, determines the amount of data the processor can handle at a given time and how it manages data transfer internally, a function sometimes referred to as the internal data bus. The 8086 offers 14 internal registers, each 16 bits (2 bytes) wide.

A key advantage of the 8086 microprocessor is its support for pipelining, which enhances processing efficiency by allowing simultaneous execution of multiple instructions. In the 8086 microprocessor, instructions are stored in memory, and the first step in fetching an instruction is calculating its physical address. Once the physical address is determined, the instruction is fetched from memory via the data bus (C-Bus) and placed in the pre-fetch queue . The size of the instruction determines how many blocks of the queue it will occupy. When the instruction is ready for execution, it moves to the control system within the Execution Unit, where decoding occurs. The control system generates an opcode that informs the microprocessor of the operation to be performed , sending signals to the relevant registers. Data is fetched from the general-purpose registers and passed to the Arithmetic Logic Unit (ALU) . While instructions are being decoded and executed, the BIU continues fetching new instructions and placing them in the pre-fetch queue. This concurrent fetching, decoding, and execution process, known as pipelining, enables parallel operation rather than the sequential execution found in earlier microprocessors like the 8085. The partitioning of the 8086 architecture into the Bus Interface Unit and Execution Unit supports this pipelining process, allowing for more efficient instruction handling.

2. Contemporary Microprocessor

The evolution of microprocessors from the earliest models to contemporary designs highlights significant advancements in architecture, performance, and functionality. Early microprocessors, such as the Intel 4004, featured simple architectures with limited processing capabilities. These early processors typically utilized 4-bit or 8-bit designs and operated at clock speeds measured in kilohertz (kHz). In contrast, contemporary microprocessors leverage 64-bit architectures, multi-core designs, and operate at clock speeds in gigahertz (GHz), allowing for the execution of billions of instructions per second.

The number of transistors on a microprocessor has increased exponentially, doubling approximately every two years. This rapid advancement has led to dramatic increases in processing power and performance.

One of the most notable advancements in modern microprocessors is the transition from single-core to multi-core architectures, enabling parallel processing and significantly improving multitasking capabilities. Additionally, modern processors incorporate advanced power management techniques, such as dynamic voltage and frequency scaling, optimizing energy consumption without compromising performance.

In terms of integration, early microprocessors were standalone units that required external memory and peripheral components. Today, many processors follow a system-on-chip (SoC) design, integrating components like memory controllers, graphics processors (GPUs), and AI accelerators directly onto the chip.

Microprocessors are not just found in computers. They are also embedded in a wide variety of other devices, including smartphones, tablets, cars, medical equipment, and industrial machinery. In fact, it is estimated that there are more microprocessors in the world than there are people.

Looking to the future, microprocessors are only going to become more powerful and sophisticated.

3. Benefits of studying the 8086 versus contemporary processors

The initial design of the 8086 microprocessor was constrained by the technological limitations of its time. However, the foundational concepts developed during its creation laid the groundwork for future innovations in processor architecture. By studying the 8086, students and professionals gain valuable insights into how specific design decisions shaped the evolution of microprocessors, influencing the development of contemporary computing systems.

A comparative analysis of the 8086 and modern processors provides a deeper understanding of critical processes such as optimization and scalability. Although contemporary processors have advanced significantly—incorporating features like multi-core architectures, cache memory, and sophisticated parallelism techniques—many core principles from the 8086 remain relevant. Understanding these foundational concepts is crucial for grasping the complexities of modern processor technologies and the ways in which they have evolved over time.
One of the primary benefits of studying the 8086 microprocessor is that it helps students and professionals comprehend the fundamental principles of microprocessors by providing a clear and straightforward example of computer architecture. Key concepts such as registers, memory addressing, and the instruction set are presented in a simplified manner, making the learning process more accessible. For instance, the 8086 instruction set, which includes fundamental operations like "MOV," "ADD," and "SUB," remains crucial to understanding how computers execute commands at the assembly level. This foundational knowledge is essential for comprehending the more advanced optimization techniques employed by modern compilers.
By understanding the limitations and challenges of the 8086, engineers can draw inspiration to innovate and improve performance or energy efficiency in today's processors.
Despite the technological gap between the 8086 and modern processors, many of the essential principles established by the 8086 persist in contemporary designs. While the 8086 utilized a 16-bit architecture and operated as a single-core processor, modern processors are based on 64-bit architectures, multi-core systems, advanced cache memory, and parallelism. Techniques like branch prediction and out-of-order execution have significantly enhanced performance. However, the fundamental principles of registers, instruction execution, and memory management introduced with the 8086 continue to form an integral part of the foundation upon which today's microprocessors are built.

To conduct a comparative analysis between the 8086 microprocessor and a contemporary microprocessor, we have selected the Intel Core i9-13900K from Intel's 13th Generation Raptor Lake series as the modern reference point. The Core i9-13900K is a widely used and advanced processor that represents the state-of-the-art in microprocessor design and performance. Its comparison with the 8086 will help highlight the technological advancements and the relevance of foundational microprocessor concepts in understanding modern architectures.

Table 1 Feature Comparison [3]

	8086	(Intel Core i9-13900K)
Number of instructions	133	1500+
Number of flags	9	Numerous
Maximum memory size	1M bytes	128GB
I/O ports	64K input, 64K output	PCIe
Number of pins	40	1700
Address bus width	16†	48-bit
Data bus width	16†	64-bit
Data types	8-bit unsigned 8-bit signed 16-bit unsigned 16-bit signed Packed BCD Unpacked BCD	8-bit, 16-bit, 32-bit, 64-bit
Addressing modes	Memory direct	Immediate, Direct, Indirect,

	Memory indirect Register Immediate Indexing	Indexed, Relative, Base + Offset, Scaled Index, more.
Introduction date	1978	2022

4. Testing and Evaluation of Results Obtained from the Emu8086 and DevC++

However, the available software simulators that are used to write and run assembly programs do not fulfill the students' expectations due to being difficult to deal with and lacking a lot of necessary GUI features.

4.1 Emu8086 and DevC++

Emu8086 is a powerful emulator and an essential tool for learning assembly language, providing a comprehensive platform for understanding early microprocessor architecture. It features an advanced source editor, assembler, disassembler, and a software emulator with a debugger, along with step-by-step tutorials, making it particularly useful for beginners. The emulator replicates the functionality of the 8086 microprocessor, offering a unified environment for writing, debugging, and testing code. Its visual interface allows real-time monitoring of registers, flags, and memory, while the Arithmetic & Logical Unit (ALU) displays the CPU's internal operations. Emu8086 supports the execution of 8086 machine code on a virtual machine, facilitating safe and detailed debugging without the need for physical hardware. The emulator also simulates peripheral devices and supports legacy operating systems like DOS, providing a comprehensive environment for studying both historical and modern computing concepts. Its simplified syntax, while retaining full 8086 compatibility, makes it ideal for learning and experimenting with assembly language across different processor generations.

Dev-C++ has been familiar to us since an early age, as it is one of the favorite tools for learning among universities and schools worldwide. The first version was released in 1998, and it is a code editor for the C/C++ programming language. [4]

4.2 Experiment

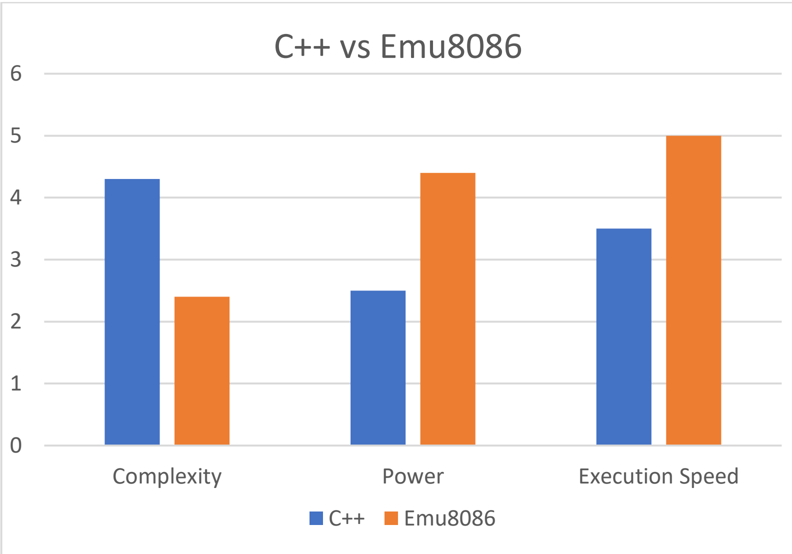
For our experiment, we will use a simple program for adding two numbers to identify the key aspects. The key aspects we will measure and compare are complexity, power, and execution speed in C++ and Emu8086.

If we compare the codes, we will notice that the number of lines of code is approximately the same: 12 lines for C++ and 14 for Emu8086. However, if we analyze the code from another perspective, C++ code is easier to understand compared to assembly language. The C++ code has a structure closer to natural language, making it easier to read and comprehend. Another advantage of C++ is its capabilities for file handling, data structures, and mathematical operations. In contrast, assembly language is a low-level language where each instruction is directly linked to a specific operation of the processor. It provides complete control over the hardware, which means dealing with many details that are not necessary for everyday programming.

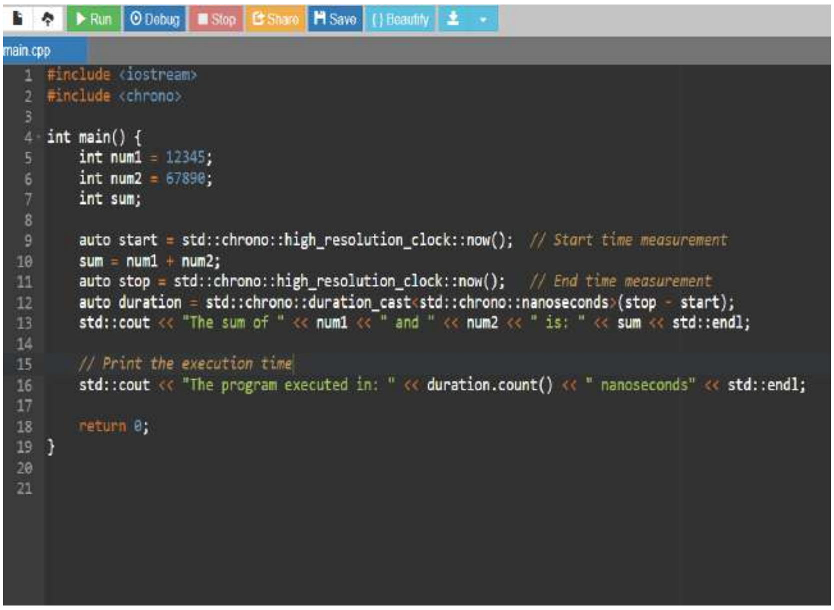
C++ is a high-level programming language with significant power, supporting the use of many libraries, which allows tasks to be performed without extensive coding. It is exceptionally well-suited for applications that require high performance. On the other hand, Emu8086 uses assembly language, which operates at a very low level, enabling control over individual bits and even processor cycles. While it provides precise control, it is not practical for developing complex applications. Assembly language played a crucial role in historical development but is less applicable to modern applications. We can conclude that C++ is more powerful for contemporary applications, while Emu8086 is effective for direct hardware interaction but less productive for modern tasks.

When executing the program in C++, the runtime varied and was expressed in nanoseconds. We found that the average execution time for five consecutive results was 112.4 nanoseconds. In contrast, assembly programs are generally faster and more efficient due to their direct access to the processor. In our emulator, we needed to follow instruction cycles to estimate speed. We monitored the program step by step, recording the cycles for each processor instruction. In our case, since we used a simple example, the difference in speed was minimal. This is because modern C++ compilers are highly optimized and can generate machine code that is very close to assembly in terms of efficiency.

According to the conducted experiment and obtained results it could be concluded by following:



a.) C++ vs Emu8086



b.) C++ code

c.)Emu8086 code

Working with assembly language in Emu8086 allows direct control over hardware resources such as CPU registers and memory, providing a deeper understanding of how modern compilers and operating systems manage these resources in high-level languages like C++. Through experiments like this, the study of the 8086 microprocessor highlights the trade-offs between the ease of coding in C++ and the performance efficiency of assembly language. While modern processors are faster and more complex, understanding the simpler 8086 helps in comprehending how far microprocessor design has come, while also showing that fundamental concepts remain relevant today. This can easily be concluded if we observe the codes mentioned above.

Conclusion

Studying the history and development of technology is a crucial aspect of understanding modern technological advancements. In the world of computer architecture, Intel's 8086 microprocessor represents one of the most significant milestones. Understanding the fundamental principles of this processor provides invaluable knowledge about the structure and functioning of today's contemporary microprocessors.

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