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The Intel 8085 microprocessor in current education

El microprocesador intel 8085 en la educación actual

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Abstract

The Intel 8085 Microprocessor launched on the market in 1976, as a substantial improvement to the Intel 8080 Microprocessor, but keeping its essential features in terms of its set of instructions in assembly language, caused a great impact in the scientific and commercial field of that time. In our study, the Intel 8085 was chosen because it is one of the most prominent and important ancestors of modern Intel Core i3, Intel Core i5, Intel Core 19, Intel Core i10 microprocessors, widely used worldwide in desktop and laptop computers. all types. But given the complexity of these modern microprocessors, we were forced to go back in time and evoke the simplicity of one of these ancestors, the Intel 8085, which with its 8-bit architecture allows us to scrutinize its most intimate secrets in an easier and more entertaining and thus be able to understand how its internal operation really is, reaching the very essence of programming, using Machine Language with its hexadecimal format to later simulate it. In this article we will make a brief introduction to the Intel 8085, we will see its internal architecture, we will give reasons why it is currently used, to finally go on to analyze a program.

Keywords: Intel 8085, Microprocessor, Machine Language, 8-bit Data Bus.

Resumen

El Microprocesador Intel 8085 lanzado al mercado en 1976, como una mejora sustancial al Microprocesador Intel 8080, pero conservando sus características esenciales en cuanto a su juego de Instrucciones en lenguaje ensamblador, causo un gran impacto en el ámbito científico y comercial de aquel tiempo. En nuestro estudio se escogió al Intel 8085 porque es uno de los ancestros más prominentes e importantes de los modernos microprocesadores Intel Core i3, Intel Core i5, Intel Core 19, Intel Core i10, ampliamente usados en todo el mundo en computadores de escritorio y laptops de todo tipo. Pero dada la complejidad de estos microprocesadores modernos nos vimos obligados a regresar al pasado y evocar la simpleza de uno de estos antepasados, el Intel 8085, que, con su arquitectura de 8 bits, nos permite escudriñar sus secretos más íntimos de una manera más fácil y amena y así poder entender como es realmente su funcionamiento Interno, llegando a la misma esencia de la programación, utilizando para ello el Lenguaje de Máquina con su formato hexadecimal para luego simularlo. En el presente articulo haremos una breve introducción del Intel 8085, veremos su arquitectura interna, daremos sustento de porque utilizarlo actualmente, para finalmente pasar a analizar un programa.

Palabras clave: Intel 8085, Microprocesador, Lenguaje de Máquina, Bus de Datos de 8 bits.

INTRODUCTION

With the advent of Industrial Automation and various modern household appliances, the use of microprocessors has become indispensable, as they are found in almost all so-called “intelligent” devices. Even these microprocessors are present inside some people with implants in the form of pacemakers, as found (Harrigal & Walters, 1990). In industry, microprocessors are found in industrial computers and especially inside Programmable Logic Controllers - PLCs as shown in (Ying, 2022). Moreover, the current trend is to interconnect microprocessors contained in networked electrical appliances in modern homes with technologies such as the Internet of Things - IoT, as can be seen in (Gomathy et al., 2021) and (Kodali et al., 2016).

On the other hand, many modern microprocessors are part of integrated systems on a single chip, where not only the microprocessor but also RAM, ROM, Input/Output Interfaces and the most diverse modules are incorporated. These devices are called microcontrollers.

Given the importance of microprocessors in our lives, it is necessary to study them. In the Latin American market are widely spread laptops with microprocessors of Intel and AMD families, but to understand its operation, we must go back to its origins, back in the years 1971 when on November 1 made its appearance The first commercial microprocessor Intel 4004 4-bit Intel Corporation, developed initially to be part of a calculator Busicom 141-PF, was the result of the interaction of brilliant minds like Ted Hoff, Stan Mazor, Federico Faggin and Masatoshi Shima. This chip is also known as the chip that changed the world. The Intel 4004 was so revolutionary that it took Intel about five years to educate engineers on how to build new microprocessor-based products (Jones, n.d.).

However, this was only the beginning, since on April 1, 1972, would come the Intel 8008 to 8 bits, then on April 1, 1974, the Intel 8080, a processor also of 8 bits in its data bus but with more features until March 1, 1976, would make its appearance the iconic Intel 8085, compatible with the Intel 8080, but more optimized since this microprocessor required only 5 volts to work which tremendously reduces the circuitry for use as a computer in addition to the costs. Then, on June 1, 1978, the Intel 8086 had a 16-bit data bus architecture, and in June 1979, the Intel 8088 had a similar architecture to the Intel 8086 but at a lower cost, but it was also slower. The rest is history. Nowadays, we have 64-bit microprocessors for everyday use, such as the Intel Core i9 or the AMD Ryzen 9, which are fully compatible with Intel processors (Timetoast, n.d.).

INTERNAL ARCHITECTURE OF THE INTEL 8085 MICROPROCESSOR

The Intel 8085 uses the Von Neumann Model or Architecture where both Instructions and Data are stored in a specific Memory Module accessible only by a single Data Bus and Address Bus.

The Intel 8085 comes in a 40-pin dual in-line layout that can fit perfectly on a breadboard for experimentation, see (Saundby, n.d.; Microwavemont, 2016). Intel 8086 is powered with 5 Volts and comes in 3 MHz (8085AH), 5 MHz (8085AH-2) and 6 MHz (8085AH-1) presentations, as can be seen in their Intel Datasheet (1987).

Figure 1
Intel 8085 Microprocessor Architecture (Learn Computer Science, 2022)

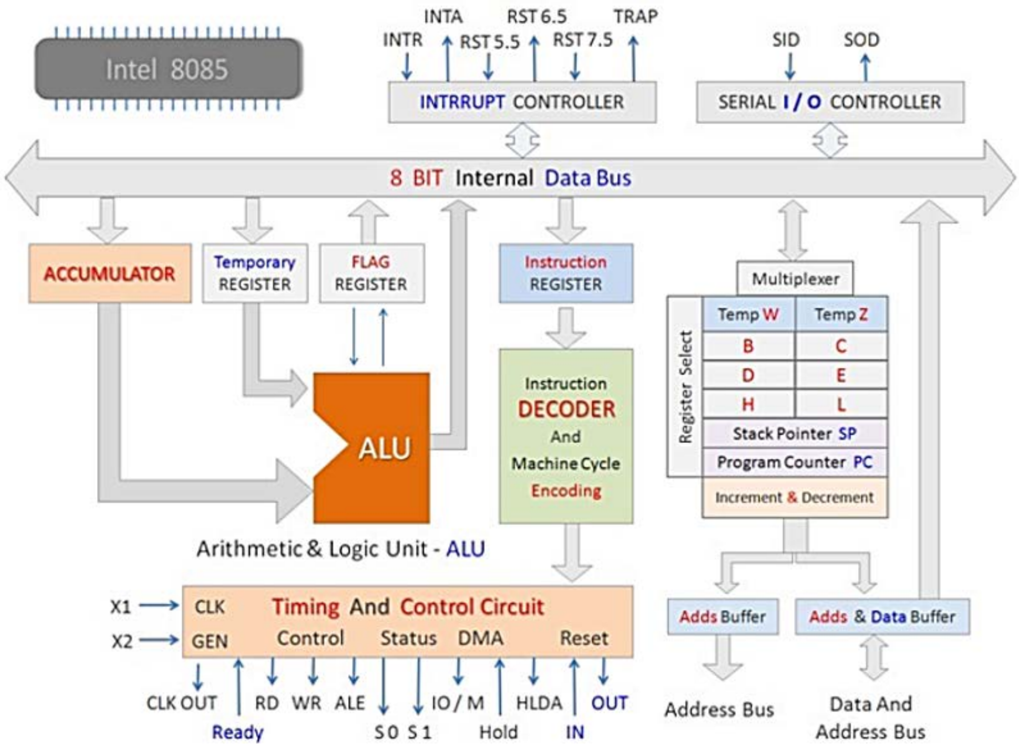


Figure 1 shows the internal architecture of the Intel 8085, which has several elements that will be briefly detailed below:

It has a Timing and control Circuit module, which is in charge of all the synchronization of this microprocessor, generating the clock pulses necessary for its operation.

The Arithmetic and Logic Unit (ALU) module is where basic arithmetic operations such as addition, subtraction, increment, and decrement and basic logic operations such as NOT, OR, AND, and XOR are performed. The 8085 has a very used register called Accumulator (A) and another Temporary Register (Temporary Register), which are the inputs to the ALU, and then in a second moment duly synchronized by the Control Unit, the result is stored in the Accumulator Register again.

There is also a Decoding Unit (Instruction Decoder) in which the instructions are decoded from the Instruction Register; that is, the microprocessor is told what to do according to the instruction code that is loaded. There are 6 general purpose registers (B, C, D, E, H and L) of 8 bits, but they can also be programmed in pairs to form 3 registers of 16 bits each (BC, DE and HL). Registers W and Z are controlled by the Control Unit only and cannot be used by the programmer.

A register called Stack Pointer (SP) is the register that will contain the location of the top address of the Stack. The Stack follows the scheme as if it were a stack of plates: last in, first out. Another register is the Program Counter (PC), which is a register that will always contain the address of the memory location from which the next instruction will have to be fetched for execution. In the Latch or Increment & Decrement Temporary Memory of 16-bit addresses, you can add one or subtract one to the contents of the Stack Pointer (SP) or the Program Counter (PC), saving valuable time since it avoids using the ALU for this purpose.

The 8085 has an Interrupt Controller that allows external peripherals to communicate with the microprocessor, interrupting and storing the process in the Stack and stopping exactly where it would have been left to give way to an external event generated by an electronic device correctly with the microprocessor and then restores the entire process prior to this event exactly where it was left extracting the data stored in the Stack. We can also include interrupts in our programming codes.

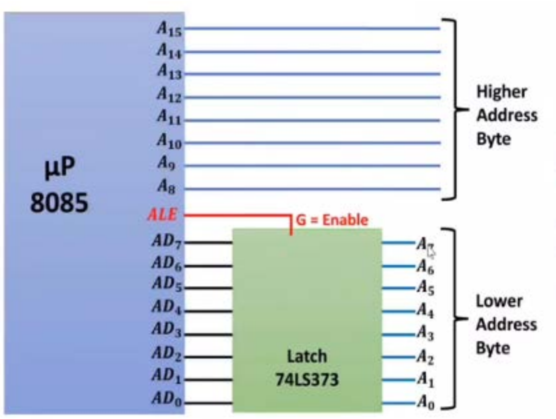
The Serial I/O Controller module is just that: it allows the input and output of information in serial form to be duly synchronized by the timing and control module. The 8085 has an 8-bit data bus, as shown in Figure 3, and also has a 16-bit Address Bus with which you can access up to 2^16 addresses or 65536 different addresses from 0000 to FFFF in Hexadecimal. The 8085 also has a Flag Register of 8 bits. However, it uses only 5, which are: S or Sign Indicator, Z or Zero Indicator, Cy or Carry Indicator, Ac or Auxiliary or Intermediate Carry Indicator and P or Parity Indicator.

It is important to emphasize, as shown in Figure 2a. that the 8 bits or one byte of the Lower Address Byte pins AD0 to AD7 are temporarily multiplexed so that the Intel 8085 can operate without problems must incorporate a Latch or Memory as the 74LS373 chip containing 8 flip-flops type D and activated with the ALE pin of the microprocessor this chip will allow that when the ALE pin is set to 1 this temporarily stores the lower 8 bits of the Address Memory. With the 8 bits or byte of the Upper Address Byte pins, there will be no problem because these are used only for the address bus exclusively. Then, in a second moment in charge of the Control Module, the same Pins AD0 to AD7 will serve as bidirectional Data bus.

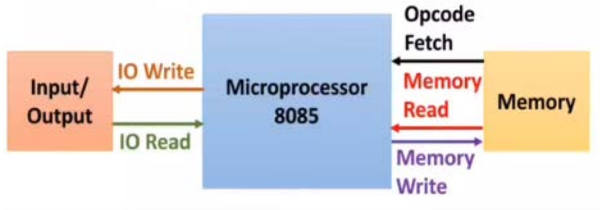
The Intel 8085 microprocessor does not work alone; it needs additional integrated circuits such as the RAM chip in which data will be read and written, the ROM chip, read-only, as well as chips that allow the connection with external devices such as a keyboard and a display to mention, this can be seen in Figure 2b.

Figure 2

Demultiplexing and Elements External to the Microprocessor.

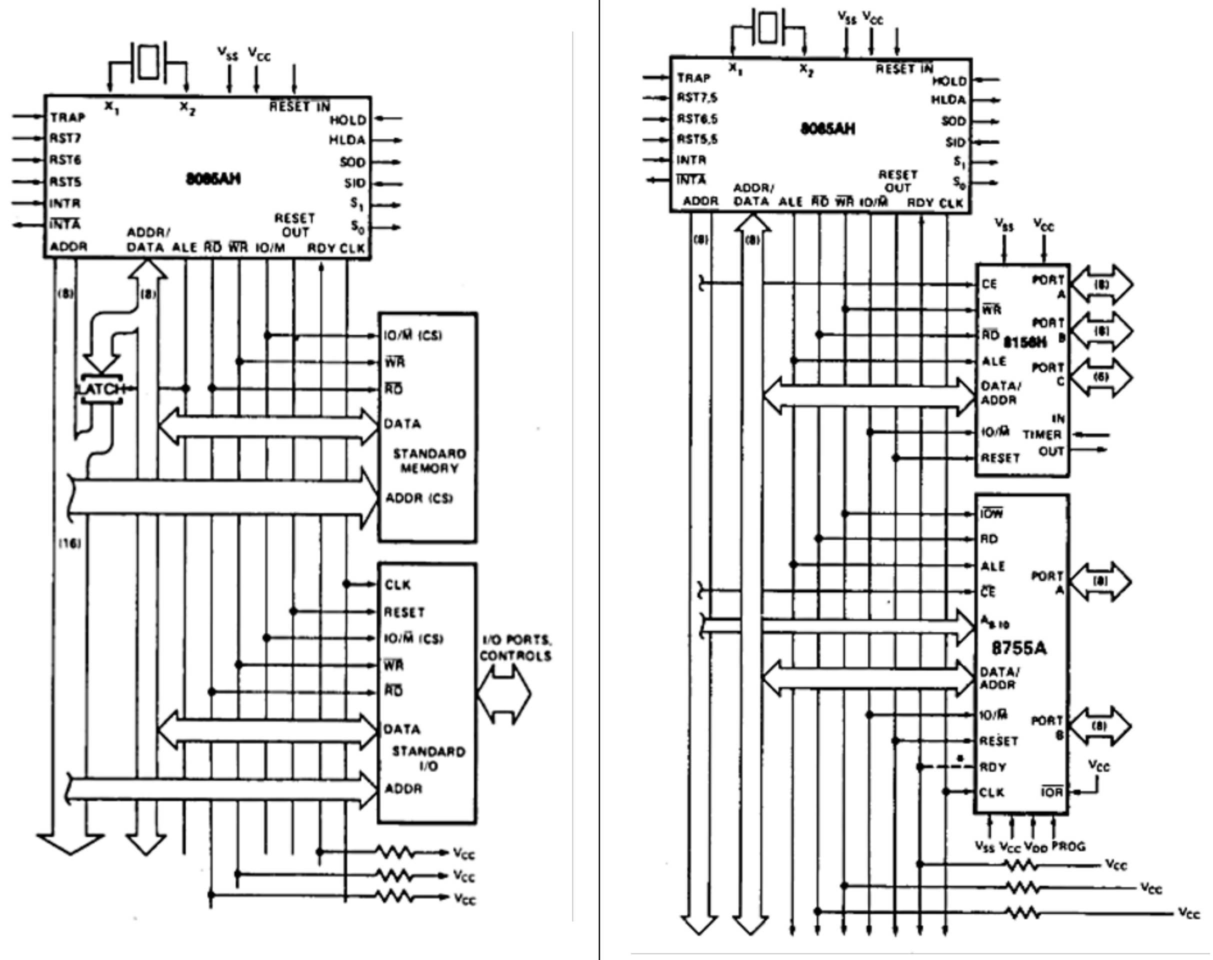


a) Demutiplexación Temporal Engineering Funda (s.f.a).



b) Interaction of the microprocessor with external elements. Engineering Funda (n.d.b).

Figure 3
Minimum System for the Intel 8085AH (Intel, 1987).



a) Minimal Circuitry with Latch	a) Minimum Circuitry without Latch

For those mentioned above, a minimum additional circuitry is required for the Intel 8085, more specifically the 8085AH series (Intel, 1987), where the Latch 74LS373, a standard memory chip (Standard Memory) and a chip with control for input and output ports (I / O Ports Controls) would be used. as shown in Figure 3a.

The Latch 74LS373 could be dispensed with if we use the following minimum configuration, also recommended by the manufacturer Intel, as shown in Figure 3b. In this configuration, the Intel 8085AH Microcontroller is used with two more chips. An 8156H chip (Intel, 1986) contains inside RAM Memory, Input and Output Ports, a Counter and a timer, and the 8755A chip (Intel, 1980) has Input and Output Ports and also an EPROM Memory, which is a Programmable Erasable ROM memory.

JUSTIFICATION FOR THE USE OF THE INTEL 8085

Because among all the Intel 8-bit microprocessors of the 1970s, the Intel 8085 Microprocessor was the most optimized and required only a 5-volt power supply to operate.

In its time, it was so crucial that the then-Soviet Union cloned it at the height of the Cold War for military use with the Russian code ИМ1821ВМ85И or IM1821VM85A in English (CPU-world, n.d.). Even with this chip, in 1997, an Autonomous

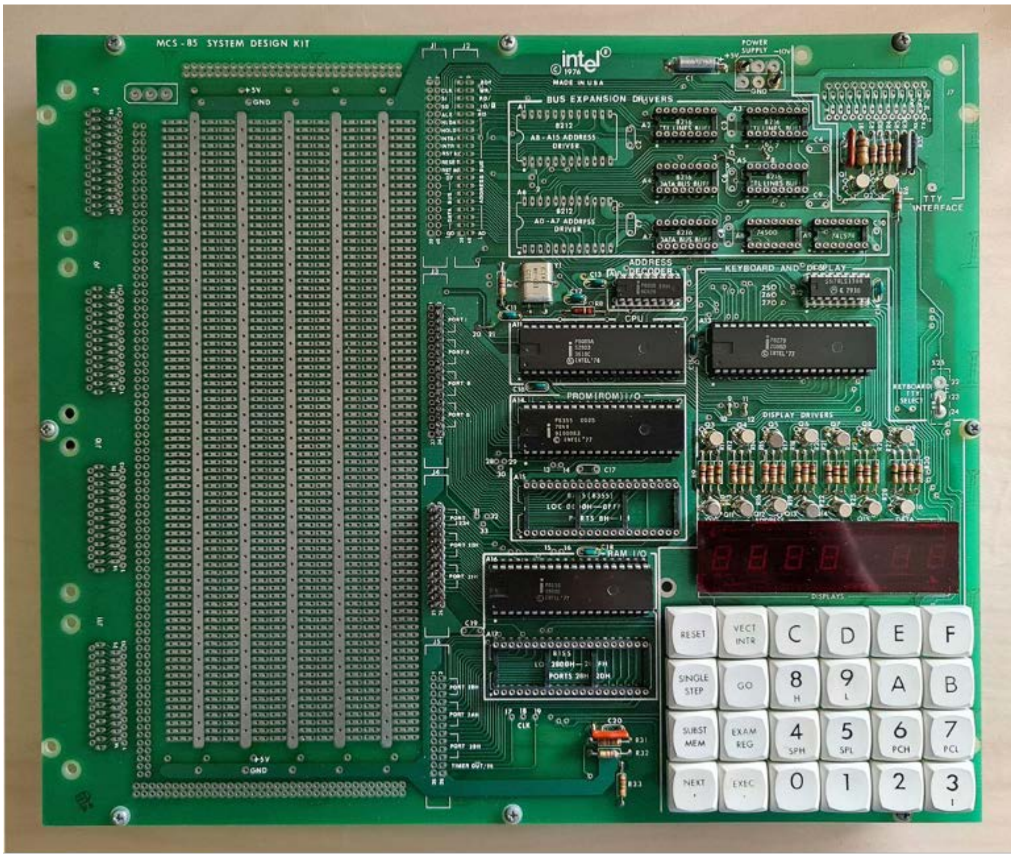
Navigation System was developed with patent RU2125237C1 (Zhukov et al., 1997). It is worth mentioning that given their importance to date, these Soviet-era microprocessors are still manufactured at the NZPP Vostok Enterprise (НЗПП Восток) in Novosibirsk (Нововосибирск), Russia (NZPP, n.d.).

Intel 8085 microprocessor is mainly employed in Indian universities and Research Institutes, as evidenced by Researchers using it from this country, such as (Jain et al., 1984, Published online in 2015) (Shreeanant Bharadwaj, 2021) (Kimasha Borah, 2015) (Sridevi & Chinni Krishna, 2016), Etc.

There are simulators, especially those developed for smartphones, which give a very similar feeling as if we were using the MCS-85 System Design Kit (SDK 85) itself, mainly if we use the simulators: Intel 8085 Simulator by Bhalotia (2014) or 8085 Simulator by SC Lab (2022). Also, there are system design kits for the Intel 8085 microprocessor for sale. Intel's original development kit was called MCS-85 and could be programmed in machine language or machine code directly using hexadecimal codes. Figure 4 shows such a kit, with hexadecimal numbers from 0 to F. plus other control keys, to enter the Program.

Figure 4

MCS-85 system design kit. (SDK 85). Retro Computing (n.d.).



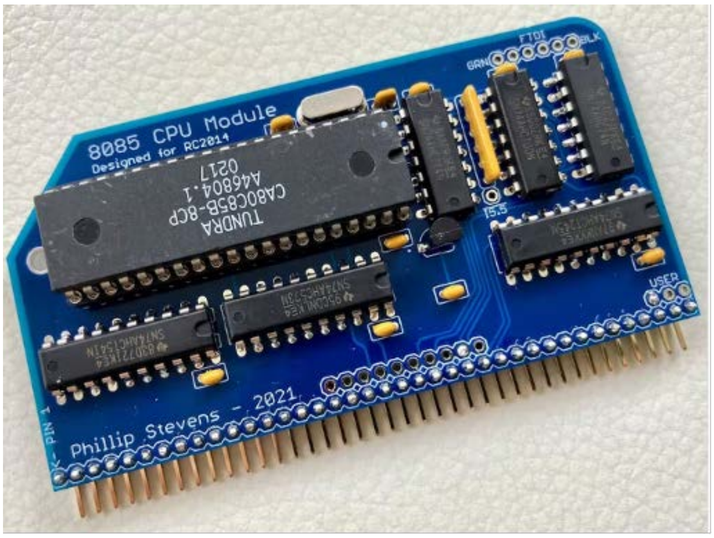
Training equipment for the design of systems with the Intel 8085 can be found in Electro Systems Associates (2022), Tesca (2022), and Pantech Solutions (n.d.). However, trainers with the Intel 8085 have also been developed in academia, as shown in Chukwujekwu (2016) and theses developed with this chip for the most diverse applications such as: "8085 Microprocessor-based Monitoring System for a 750 cc Honda Motorcycle" by Leet (1988), "Interfacing an 8085-based Microcontroller: A Practical Approach to Develop Computer Application Skills" by Li and Zagari (2001), "Designing an Electronic Organ using the 8085 Microprocessor" by Kerimoglu and Ibrahim (2006).

There is audiovisual material that makes us understand more easily the Intel 8085 Microprocessor as in Engineering Funda (n.d.), Learn Computer Science (n.d.), Bharat Acharya Education (n.d.), Ruiz (n.d.), Etc. and there are also specialized books that allow us to deepen the understanding and application of this microprocessor as in Intel (1977, 1978, 1983), Stallings (2005), Kaushik (2010), Novillo and Hernandez (2015), Vijayaraghavan (n.d.), Etc.

It is still used in the form of modules such as the "CPU 8085 for RC2014", which is a hardware module with a Central Processing Unit - Intel 8085 CPU and software fully integrated with the RC20014 (Z80) which is a modular computer based on the Z80 microprocessor. Moreover, supports CP/M, which is a single-user operating system, and Microsoft Basic (Stevens, 2021). as seen in Figure 5.

Figure 5

8085 CPU module designed for RC2014. (Stevens, 2021).



Finally, a model of the Intel 8085 in the digital electronic circuit description language called VHDL is available in Jovanov and Tentov (2014).

PROGRAMMING THE INTEL 8085

In programming, there are high-level languages such as C or C++ that need a compiler to convert this language to machine language. There are also Low-Level Languages such as Assembly Language, which are specific to each microprocessor but also need to convert their instructions called mnemonics (mnemonic) which are abbreviations of these instructions, to Machine Language.

Machine Language is the language understood by the Microprocessors or Microcontrollers, and it is a language based on Zeros (O) and Ones (1); that is to say, it works with the binary numbering system but to be able to represent them more easily the Hexadecimal numbers are used since four binary numbers are equivalent to one hexadecimal number as shown in table 1.

Table 1

Table of Equivalences of Hexadecimal to Binary Numbers.

No. Hexadecimal	No. Binario
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110

7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

The Intel 8085 Microprocessor has 246 instructions represented by 8-bit binary values, expressed in hexadecimal numbers for easier understanding. It is also called Opcode or Instruction Byte; see Tatla (n.d.).

On the other hand, the Intel 8085 uses the so-called Addressing Modes, which are the different specification formats of the operands. We have the following (Engineering Funda, 2022): Immediate Addressing Mode, in this mode, the 1 or 2-byte Data specified in the Instruction is directly transferred in the register, for example, in the MVI instruction B,12H where the data 12H is transferred to Register B. Register Addressing Mode, in this mode the Data is specified between registers, for example in the MOV Instruction A, B where the Data from Register B will be copied into Register A. Direct Addressing Mode, in this mode the Operand Address is specified in the Instruction itself, for example in the LDA Instruction 2000H where Register A will get the data from the contents of Address 2000H. In indirect Addressing Mode, in this mode the address of the operand is stored in the registers, for example, STAX B, where the content or data of A is stored in the address pointed to by the paired registers BC. and the Implicit Addressing Mode, in this mode the operand is implicit in the Instruction, for example, in the CMC instruction where with this Instruction the indicator bit or Carry flag Cy of the Indicator or Flag Register is complemented, i.e. if Cy was at zero it is changed to one and if it was at One to zero. It is worth mentioning that the instructions can occupy one, two or even three bytes in memory, depending on the Instruction used.

We will detail some of the instructions, which we will divide by their application. Some of the Data Transfer Instructions are MOV A, B where B will be copied to A; MOV A, M where the content pointed to by the paired Register [HL] will be copied to Register A; MVI A, 44H where the data 44H will be transferred or copied to Register A; MVI M, 35H where the Data 35H will be copied to the Address pointed to by Register [HL].

Some Arithmetic Instructions are: ADD B that is A = A + B, wherein the first moment, the Accumulator Register A is added with Register B and in a second moment, the result is Stored in A; ADD M that is A = A + [HL] where in a first moment the Accumulator Register A is added with the content of the Address indicated in the paired Register [HL] and a second moment the result is Stored in the Accumulator Register A; ADI 25H that is A = A + 25H where in a first moment the Contents of the Accumulator Register A plus the data 25H will be added, and in a second moment the result is stored in the Accumulator Register A; INR B that is B = B + 1 that is in a first moment 1 is added to the contents that B has and in a second moment the result is stored in the Register B.

Some Logical Instructions are ANA B, which is A = A AND B, where in the first moment, the AND Logical Operation will be performed. In a second moment the result will be stored in the Accumulator Register A. ANA M this is A = A AND [HL] where in a first moment the AND Logical Operation will be performed between Register A and the Content of the Address pointed by the Matched Register [HL] and in a second moment the result will be stored in the Accumulator Register A; ANI 47H this is A = A AND 47H where in a first moment the AND Logical Operation will be performed between the content of Register A and the Data 47H and in a second moment the result will be stored in the Accumulator Register A.

Some Branching and Control Instructions are: JMP 4000H this is PC = 4000H where the Program Counter (PC) will be loaded at Address 4000H this means that it is an unconditional jump instruction; JZ 4500H this is if Z =1 then PC = 4500H, where the Program Counter PC will be loaded at Address 4500H if and only bit Z of the Indicator Register is 1; CALL 4700H this is the current value of PC is saved in the Stack and then assigned to PC = 4700H, then the microprocessor continues to advance in the program until it encounters the RET Instruction and the value of PC that had been saved in the Stack is resumed and continues with the program where it was previously, so the CALL instruction is used to make subroutines; CZ 4500H that is if the Indicator bit or Z Flag of the Indicator Register is equal to 1 then the current value of PC is saved in the Stack and then assigned to PC = 4500H then the microprocessor continues to advance in the program until it finds the RET Instruction and the value of PC that had been saved in the Stack is resumed and continues with the program where it was before.

However, in order to make the Intel 8085 Microprocessor work, we now need a program, which we have chosen, The Fibonacci Series algorithm developed in Scratch Learners (2020), as shown in Table 2.

Table 2

Fibonacci Series Program for Intel 8085 (Scratch Learners, 2020).

MEMORY Addresses (16 bits)	Machine Code (Hex)	Assembler language	Comment
2000	21	LXI H, C050H	Cargo C050H en HL
2001	50		Data (Address)
2002	C0		Data (Address)
2003	3A	LDA D000H	Loads the Value or Content of the address D000H in the Accumulator A.
2004	00		Data (Address)
2005	D0		Data (Address)
2006	57	MOV D, A	D = A (assigns A in D)
2007	06	MVI B, 00H	B = 00H
2008	00		Data (Value or Content)
2009	0E	MVI C, 01H	C = 01H
200A	01		Data (Value or Content)
200B	3E	MVI A, 00H	A = 00H
200C	00		Data (Value or Content)
200D	77	loop MOV M, A	Loads the Contents of A into the address pointed to by HL
200E	81	ADD C	C = A + C
200F	41	MOV B, C	B = C (asigna C en B)
2010	4F	MOV C, A	C = A (Asigna A en C

2011	78	MOV A, B	A = B (Asigna B en A)
2012	23	INX H	HL = HL + 1
2013	15	DCR D	D = D - 1
2014	C2	JNZ loop	Salta si Z = 0
2015	0D		Data (Address)
2016	20		Dato (Address)
2017	76	HLT	ALTO = FIN
2018	00	NOP	Wait 4 machine states
. . .	...	...	. . .
C050			Answer: Fibonacci Fact 1 = 00H
C051			Answer: Fibonacci Fact 2 = 01H
C052			Answer: Fibonacci Datum 3 = 01H
C053			Answer: Fibonacci Datum 4 = 02H
C054			Answer: Fibonacci Datum 5 = 03H
C055			Answer: Fibonacci Datum 6 = 05H
C056			Answer: Fibonacci Datum 7 = 08H
C057			Answer: Fibonacci Datum 8 = 0DH
C058			Answer: Fibonacci Datum 9 = 15H
C059			Answer: Fibonacci Datum 10 = 22H
C05A			Answer: Fibonacci Datum 11 = 37H
CO5B			Answer: Fibonacci Datum 12 = 59H
C05C			Answer: Fibonacci Datum 13 = 90H
C05D			Answer: Fibonacci Datum 14 = E9H
. . .			
D000	0E		Input Data "n" number of Fibonacci series Elements In this case 0Eh ie 14 in decimal
D001			

More programs for Intel 8085 can be found in Saravanakumar (n.d.).

EXECUTION OF THE PROGRAM FOR THE INTEL 8085

Finally, now we have to decide where to run the program for which we can acquire a System Development Kit for the Intel 8085 as the one provided by Tesca (2022) - 8085 Microprocessor Trainer or run it in one of the simulators for Android smartphones as Bhalotia (2014) - Intel 8085 Simulator. Programming is relatively simple. Just enter the code in hexadecimal format in sequential order as presented in Table 2 and follow the directions either from the purchased Development Kit or from the chosen simulator.

CONCLUSIONS

The study of the Intel 8085 Microprocessor, due to its reduced architecture of 8 bits of data in comparison to the current 64-bit microprocessors, allows us to understand its internal operation in an easier and faster way.

The Intel 8085 Microprocessor, having few instructions in relation to modern microprocessors such as the Intel Core i3, i5, i7, and i10 family, is easier to program at the machine code level.

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