Course guides
230370 - DBC - Designing and Building an 8-Bit Computer

Last modified: 06/05/2019

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.

Degree: **Academic year:** 2019 **ECTS Credits:** 2.5
Languages: English

LECTURER

Coordinating lecturer: Jorge García Mateos

Others: Jorge García Mateos

PRIOR SKILLS

Basic knowledge of the different digital logic gates.

TEACHING METHODOLOGY

Laboratory sessions.

LEARNING OBJECTIVES OF THE SUBJECT

We believe that the best way to understand how computers work is to build one from scratch. The main puropose of our simple computer is to introduce all the crucial ideas behind computer operation. Furthermore, we will build it on breadboards and using TTL logic chips for the logic gates and registers, avoiding FPGA approaches for building processors. Our approach is complementary for a better and deeper understanding of processors.The computer that we will build features a 4-bit address bus, four 8-bit registers and 16 bytes of RAM. Each instruction tales 5 cycles, 2 fetch and 3 execute, 4-bits instruction register and 2-bytes controlling word. The computer will be bus-oriented, with outputs to the 8-bit main bus three-state or open-collector, allowing for orderly data transfers.At the end of the seminar, the student will be able of:- Build and design a computer from scratch.- Understand deeply the working of a computer.- Build an 8-bit computer from TTL chips (logic gates and flip-flops), on breadboards.- Design the control unit, define its different instructions and program its microcode on EEPROM memory.- Program the computer built with the created machine code and assembler.

STUDY LOAD

Type	Hours	Percentage
Hours small group	20	32.26
Self study	42,5	67.74

Total learning time: 62 h

CONTENTS

Introduction and Clock

Description:
We are going to design and build our computer emphasizing a modular arquitecture based on the different registers attached to the 8-bit bus. No attempt has been made to keep all control circuits in one block called the control unit, all input-output circuits in another block called the I/O unit, etc.The first one of the modules that we will design and build is the clock. The clock of the computer is used to synchronize all operations. The clock we're building is based on the popular 555 timer IC. Our clock is adjustable-speed (from less than 1Hz to a few hundred Hz). The clock can also be put into a manual mode where you push a button to advance each clock cycle. This will be a really useful feature for debugging the computer.

Registers

Description:
Most CPUs have a number of registers which store small amounts of data that the CPU is processing. In our simple CPU, we will build three 8-bit registers: A, B, and IR. The A and B registers are general-purpose registers. IR (the instruction register) works similarly, but we will only use it for storing the current instruction that is being executed.

Arithmetic and Logic unit (ALU)

Description:
The arithmetic logic unit (ALU) part of a CPU is capable of performing various arithmetic, bitwise, and comparison operations on binary numbers. In our simple breadboard CPU, the ALU is just able to add and subtract. It is connected to the A and B registers and outputs either the sum of A+B or the difference of A-B.

Memory Address Register (MAR) and Rand Access Memory (RAM)

Description:
The random access memory stores the program the computer is executing as well as any data the program needs. The memory address register is a 4-bit register, so our breadboard computer uses 4-bit addresses. We have a RAM with 16 words, each word of 8-bit, i.e. a total of 16 bytes of RAM, limiting the size and complexity of programs it can run. This is by far its biggest limitation.

Output Register (OUT)

Description:
The output register is similar to any other register (like the A and B registers) except rather than displaying its contents in binary on 8 LEDs, it displays its contents in decimal on 7-segment displays.

Program Counter (PC)

Description:
The program counter counts in binary to keep track of which instruction of the program the computer is currently executing.

Control logic (CL)

Description:
The control logic is the heart of the CPU of the computer. It is what defines the opcodes the processor recognizes and what happens when it executes each instruction.

Programming and running the computer.

Description:
Finally we will program our computer with some simple programs.

GRADING SYSTEM

Development and delivery of lab assignments.

BIBLIOGRAPHY

Basic:
- Nisan, N.; Schocken, S. The Elements of computing systems : building a modern computer from first principles. Cambridge, Massachusetts ; London: MIT Press, 2005. ISBN 026214087X.
- Fernández, G. Curso de ordenadores: conceptos básicos de arquitectura y sistemas operativos. 2a ed. Fundación Rogelio Segovia para el desarrollo de las telecomunicaciones, 2004. ISBN 978-8474023121.
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Complementary:
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- Scott, J.C. But how do it know?: the basic principles of computers for everyone. Florida: John C. Scott, 2009. ISBN 9780615303765.