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L08: LC-3 Introduction

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Overview

LC-3 Basic

LC-3 Micro-Architecture



Overview

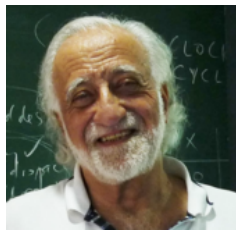
LC-3 Basic

LC-3 Micro-Architecture



LC-3b

- ▶ LC-3: **Little Computer 3**
- ▶ Relatively simple instruction set
- ▶ Most used in teaching for CS & CE
- ▶ Developed by Yale Patt@UT & Sanjay J. Patel@UIUC



LC-3 Architecture

- ▶ RISC – only 15 instructions
- ▶ 16-bit data and address
- ▶ 8 general-purpose registers (GPR)

Plus 4 special-purpose registers:

- ▶ Program Counter (PC)
- ▶ Instruction Register (IR)
- ▶ Condition Code Register (CC)
- ▶ Process Status Register (PSR)



Memory

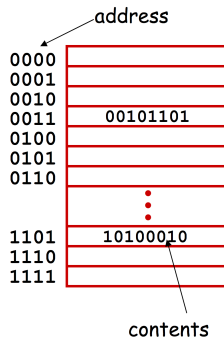
$2^k \times m$ array of stored bits:

Address

- ▶ unique (k -bit) identifier of location
- ▶ LC-3: $k = 16$

Contents

- ▶ m -bit value stored in location
- ▶ LC-3: $m = 16$



Basic Operations:

- ▶ READ (Load): value in a memory location \rightarrow the Processor
- ▶ WRITE (Store): value in the Processor \rightarrow a memory location



Interface to Memory

How does the processing unit get data to/from memory?

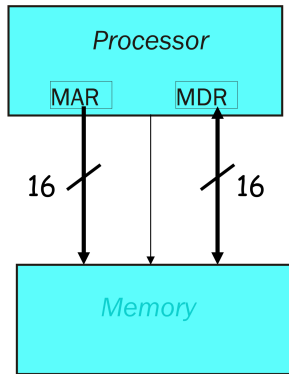
- ▶ **MAR**: Memory Address Register
- ▶ **MDR**: Memory Data Register

To LOAD from a location (A):

1. Write the address (A) into the MAR.
2. Send a “read” signal to the memory.
3. Read the data from MDR.

To STORE a value (X) into a location (A):

1. Write the data (X) to the MDR.
2. Write the address (A) into the MAR.
3. Send a “write” signal to the memory.



CPU-only Tasks

In addition to input & output a program also:

- ▶ Evaluates arithmetic & logical functions to determine values to assign to variable.
- ▶ Determines the order of execution of the statements in the program.
- ▶ In assembly this distinction is captured in the notion of **arithmetic/logical**, and **control** instructions.



Processing Unit

Functional Units:

- ▶ ALU = Arithmetic/Logic Unit
- ▶ could have many functional units.
- ▶ some of them special-purpose (floating point, multiply, square root, . . .)

Registers

- ▶ Small, temporary storage
- ▶ Operands and results of functional units
- ▶ LC-3 has eight registers (R0, . . . , R7), each 16 bits wide

Word Size

- ▶ number of bits normally processed by ALU in one instruction
- ▶ also width of registers
- ▶ LC-3 is 16 bits



Instructions

The instruction is the fundamental unit of work.

Specifies two things:

- ▶ opcode: operation to be performed
- ▶ Operands: data/locations to be used for operation

Three basic kinds of instructions:

- ▶ Computational instructions
- ▶ Data-movement instructions
- ▶ Flow-control instructions



Instruction Encoding



- ▶ in LC-3, the most-significant **four** bits contain the instruction's OPCODE always.
- ▶ The meaning of the other bits changes according to the instruction.
- ▶ Look up the “LC-3b-ISA.pdf” find all 16 instruction format descriptions



LC-3 v.s. MIPS

LC-3

1. 16 bit
2. NO floating point instruction
3. 8 registers
4. NO hardwired register value
5. Only has AND, NOT, and ADD

MIPS

1. 32 bit
2. Floating point instruction
3. 32 registers
4. \$0 is hardwired to 0
5. Full complement of arithmetic, logical, and shift operations



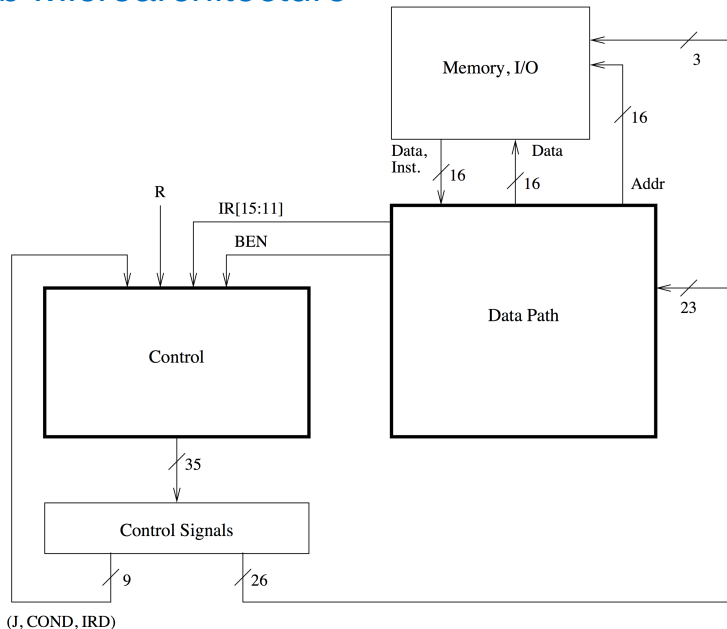
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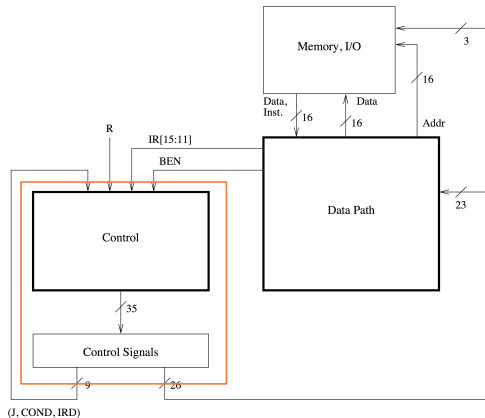
LC-3b Microarchitecture



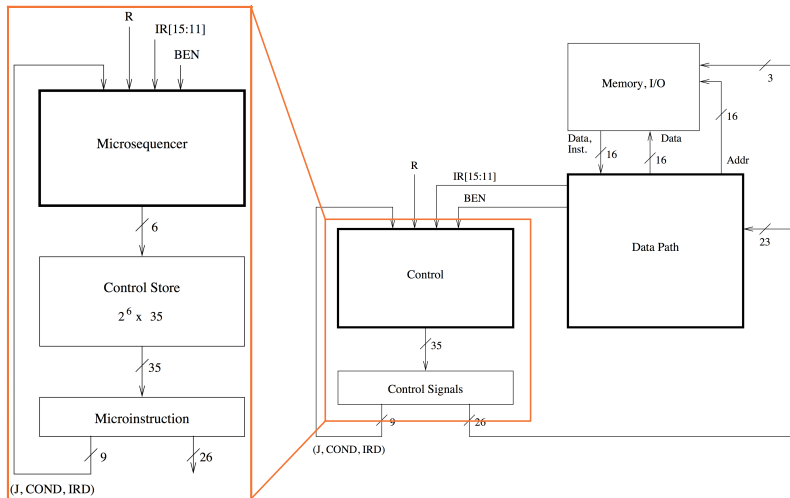
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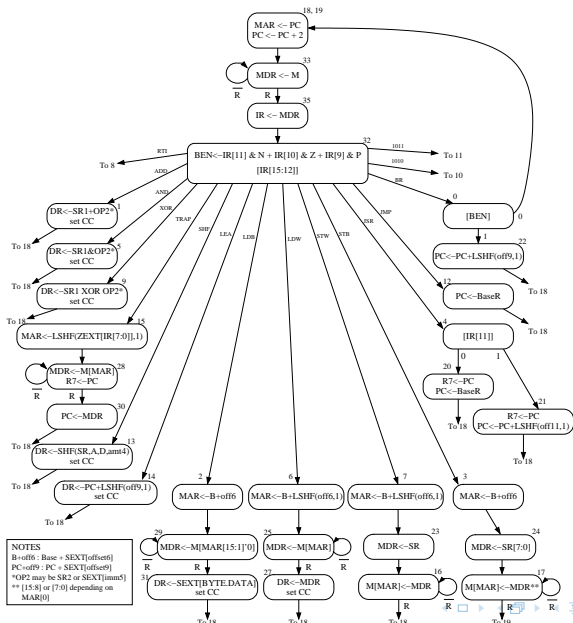
LC-3b Control Structure



LC-3b Control Structure



How's Microsequencer Actually Working?



LC-3b Datapath

