Microprogrammed Control

Chapter 17

ELECTRICAL & COMPUTER ENGINEERING
THE UNIVERSITY OF NEW MEXICO

From chapter 16…

- Implementation of the control unit:
  - Hardwired
    - Essentially a combinatorial circuit
  - Microprogrammed
    - An alternative to a hardwired implementation.
    - It consists of a sequence of instructions in a microprogramming language.

Introduction

- The term *microprogram* was coined by Wilkes in early 1950s
- The proposal was a control unit design that was organized and systematic and avoided the complexities of a hardwired implementation
- It would require a fast, relatively inexpensive control memory => 1964 - IBM

Microinstructions (1)

- To implement a CU as an interconnection of basic logic elements is no easy task.
- The design must include logic for sequencing through micro-operations for: executing micro-operations, interpreting codes, and making decisions based on flags.
- Difficult: to design and test such a piece of hardware, and to change the design if one wishes to add a new machine instruction.
- An alternative: to implement a microprogrammed control unit.

Microinstructions (2)

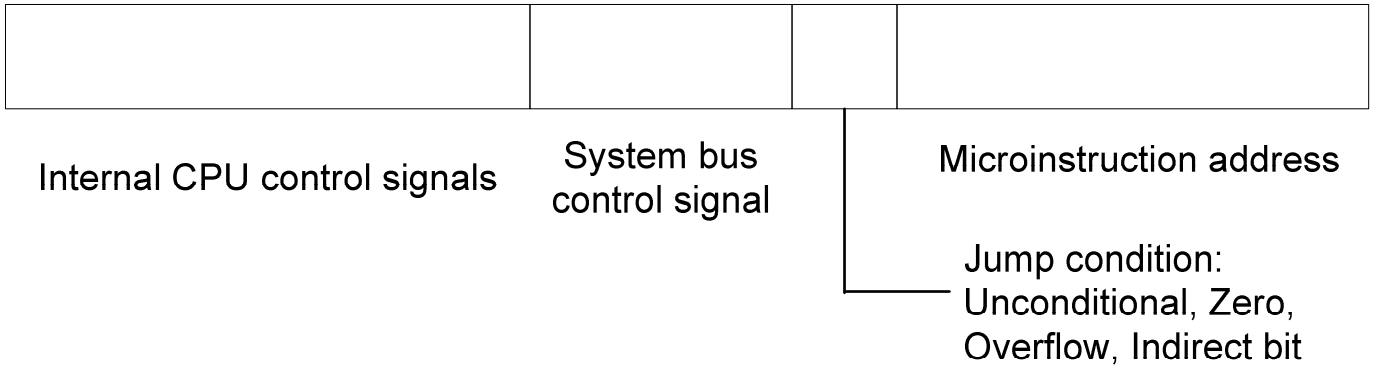
Micro-operations	Timing	Active Control Signals
Fetch:	t1: MAR ← (PC)	C_2
	t2: MBR ← Memory PC ← (PC) + 1	C_5, C_R
	t3: IR ← (MBR)	C_4
Indirect:	t1: MAR ← (IR(Address))	C_8
	t2: MBR ← Memory	C_5, C_R
	t3: IR(Address) ← (MBR(Address))	C_4
Interrupt:	t1: MBR ← (PC)	C_1
	t2: MAR ← Save-address PC ← Routine-address	
	t3: Memory ← (MBR)	C_{12}, C_W

C_R = Read control signal to system bus.
C_W = Write control signal to system bus.

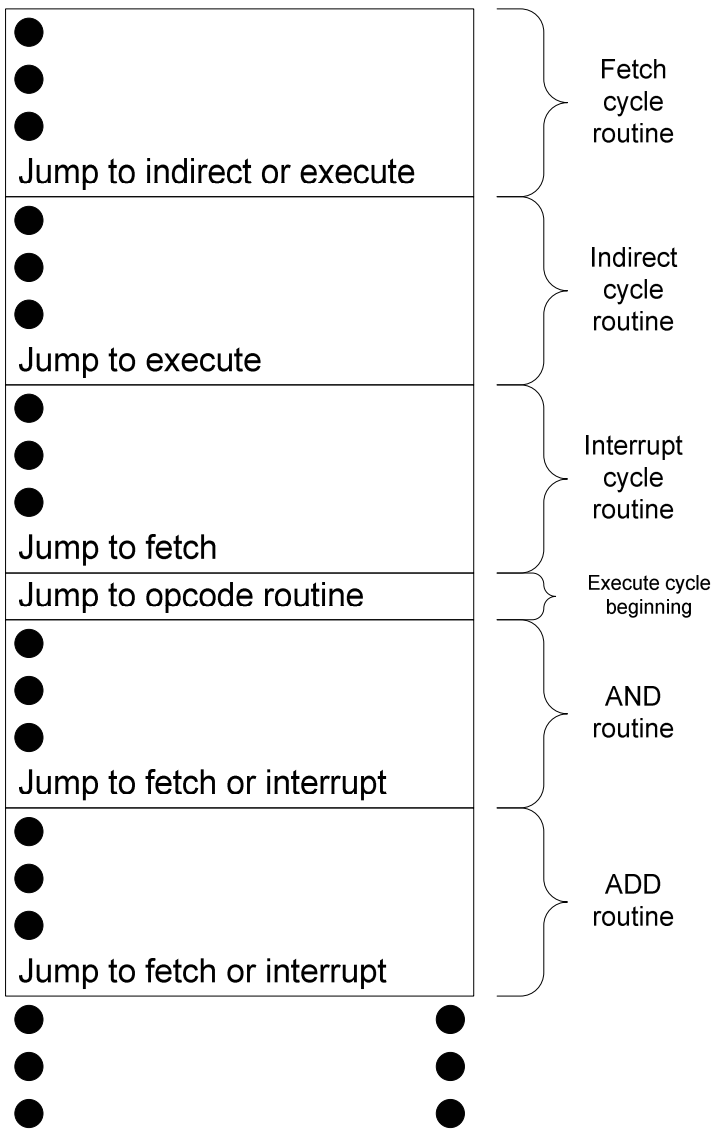
- This is a language: *microprogramming language*.
- Each line describes a set of micro-operations occurring at one time: *microinstruction.*
- A sequence of instructions: *microprogram* or *firmware* (a midway between hardware and software).

Microinstructions (3)

- For each micro-operation: generation of control signals.
- *Control word*: each bit represents one control line.
- *Horizontal microinstruction*: bits for the control signal, microinstruction address, and jump condition.

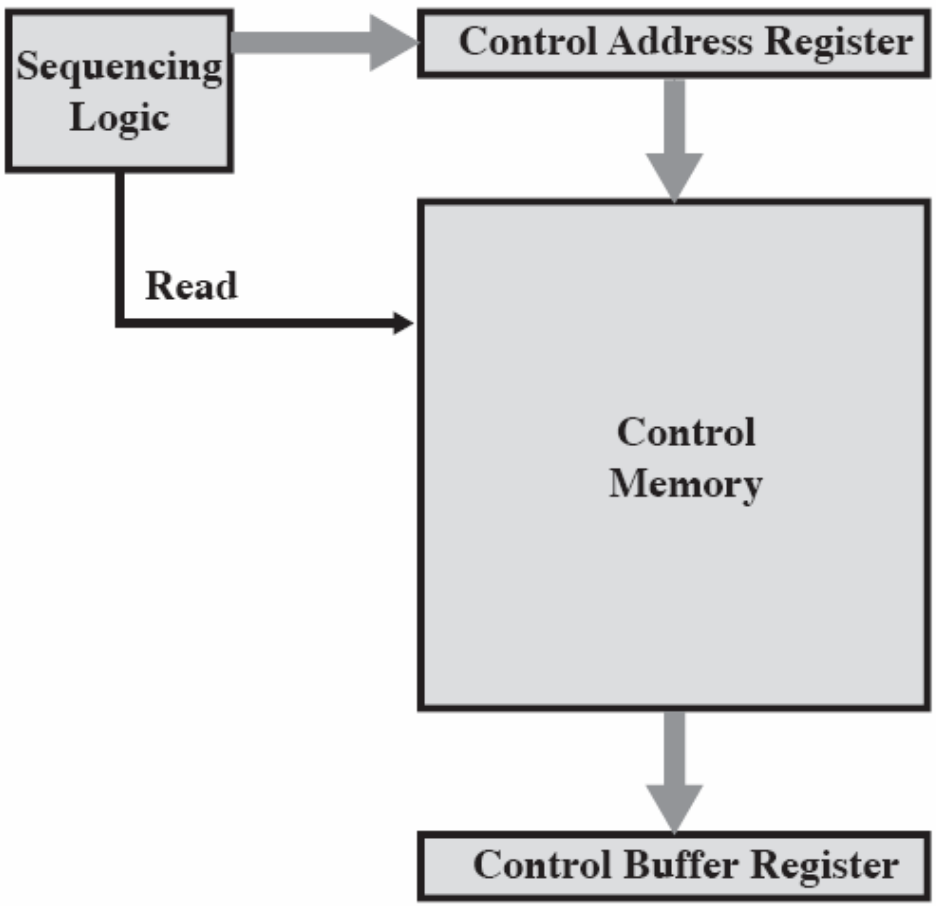


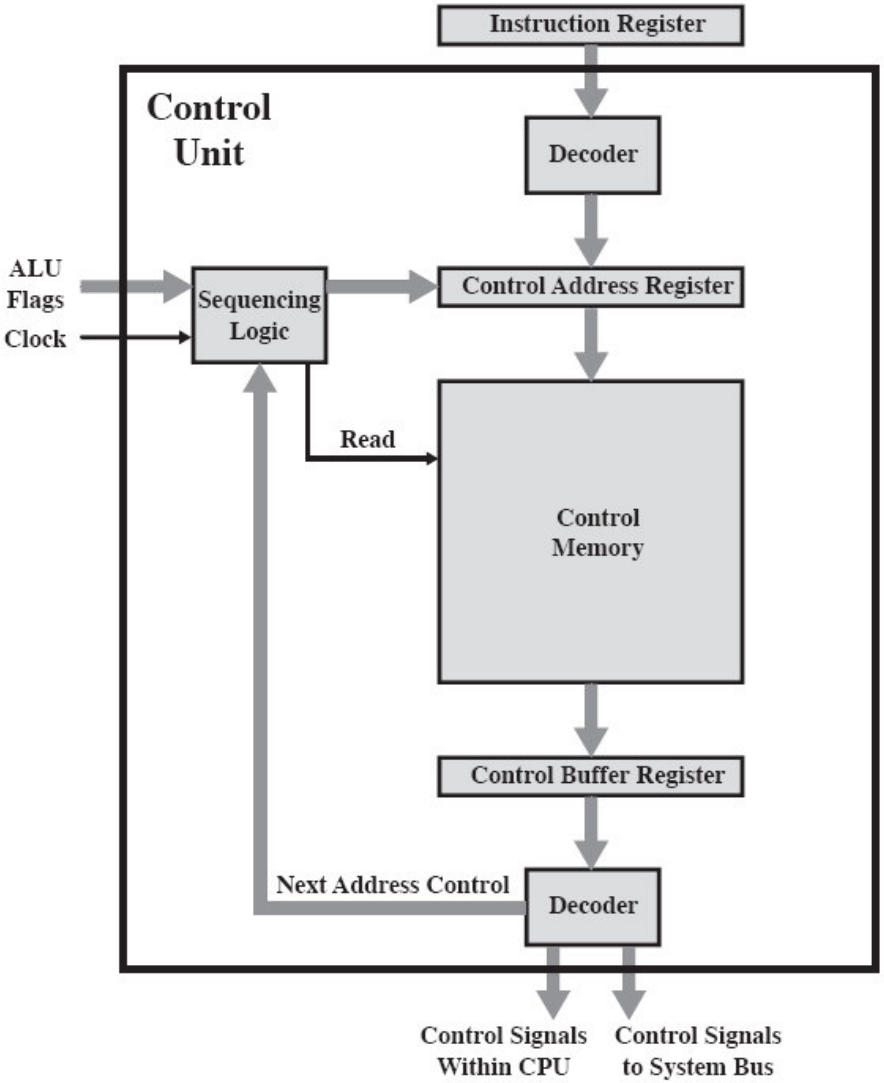
Organization of Control Memory



- The microinstructions can be arranged in a *control memory*.
- This figure is a concise description of the complete operation of the control unit (it can be used like a way to implement the control unit)

Control Unit Microarchitecture





Functioning of Microprogrammed Control Unit

Control Unit functions (1) (during one clock pulse)

1. To execute an instruction, the sequencing logic unit issues a READ command to the control memory.
2. The word whose address is specified in the control address register is read into the control buffer register.
3. The content of the control buffer register generates control signals and next address information for the sequencing logic unit.

Control Unit functions (2) (during one clock pulse)

4. The sequencing logic unit loads a new address into the control address register based on the next-address information from the control buffer register and the ALU flags.
   - Get the next instruction
   - Jump to a new routine based on a jump microinstruction
   - Jump to a machine instruction routine

Microinstructions for Wilkes Example

ELECTRICAL & COMPUTER ENGINEERING
THE UNIVERSITY OF NEW MEXICO

Advantages and Disadvantages

- Advantages:
  - It simplifies the design of the CU
  - Cheaper and less error-prone to implement
  - Decoders and sequencing logic are very simple pieces of logic
  - *Hardwired:* CU contains complex logic for sequencing micro-operations
- Disadvantages:
  - Slower than a hardwired unit of comparable technology.
- CISC: microprogrammed control
- RISC: hardwired control

Microinstruction Sequencing

- Two basic tasks performed by a microprogrammed control unit are as follows:
  - Microinstruction sequencing
  - Microinstruction execution
- In designing a control unit, these tasks must be considered together, because both affect the format of the microinstruction and the timing of the control unit.

Design considerations (1)

- **The size of the microinstruction**: about the minimizing the size of the control memory reduces the cost of that component.
- **The address-generation time**: about to execute microinstructions as fast as possible.

Design considerations (2)

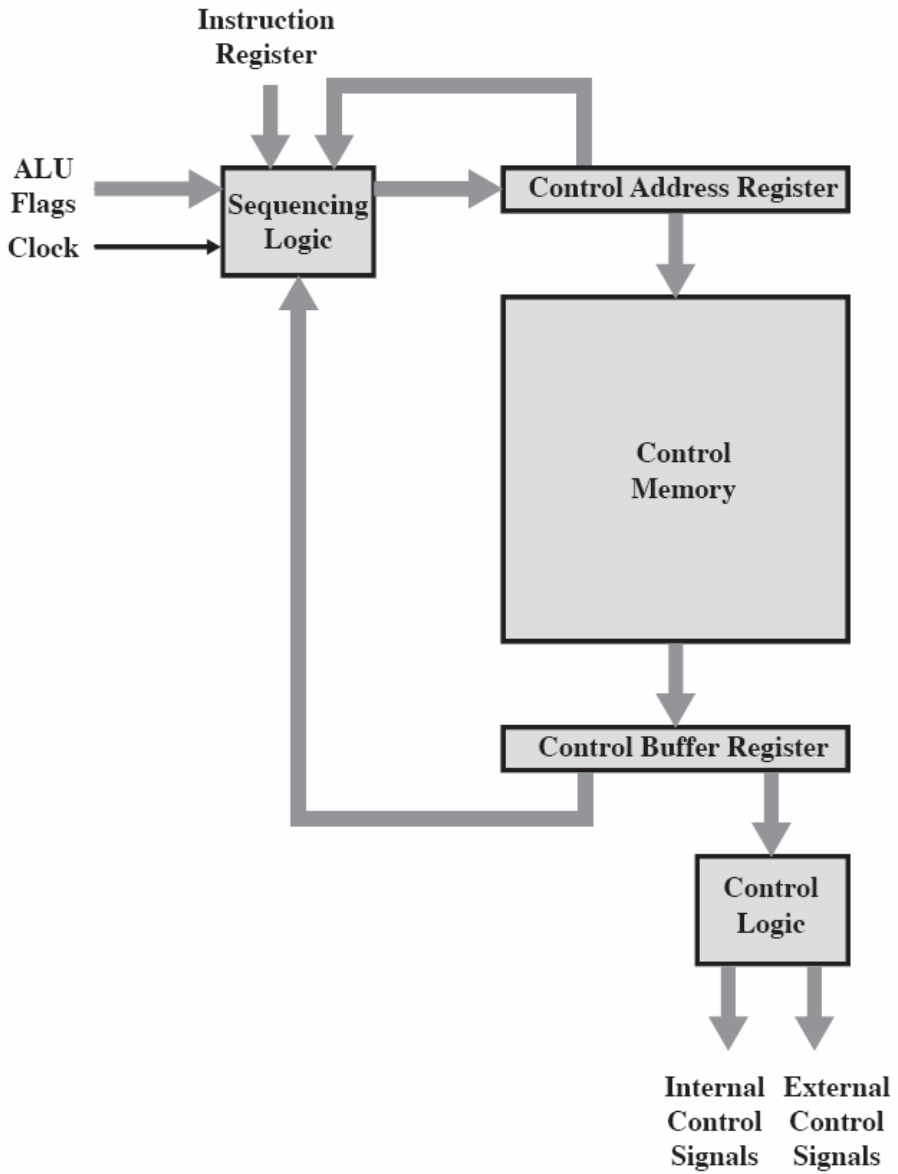
- In executing a microprogram, the address of the next microinstruction to be executed in one of these categories:
  - Determined by instruction register
  - Next sequential address
  - Branch

Sequencing Techniques

- Based on the current microinstruction, condition flags, and the contents of the instruction register, <u>a control memory address must be generated for the next microinstruction</u>.
- Techniques:
  - Two address fields
  - Single address field
    - Address field
    - Instruction register code
    - Next sequential address
  - Variable format

Address generation techniques

Explicit	Implicit
Two-field	Mapping
Unconditional branch	Addition
Conditional branch	Residual control



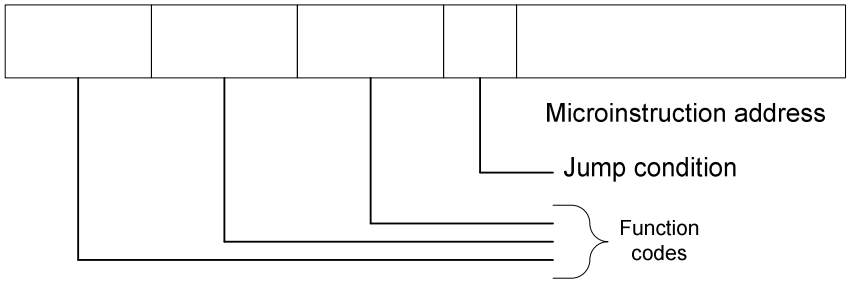
Microinstruction Execution

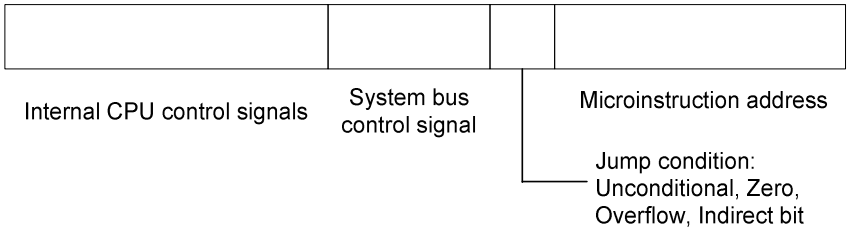
ELECTRICAL & COMPUTER ENGINEERING
THE UNIVERSITY OF NEW MEXICO

A Taxonomy of Microinstruction

- Microinstructions can be classified in a variety of ways.
- Distinctions that are commonly made in the literature include:
  - Vertical / horizontal
  - Packed / Unpacked
  - Hard / soft microprogramming
  - Direct / indirect encoding

Vertical / horizontal

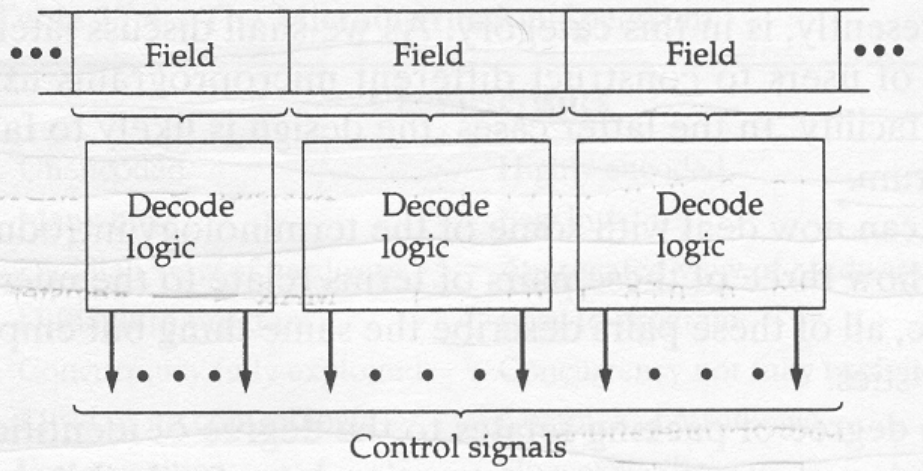




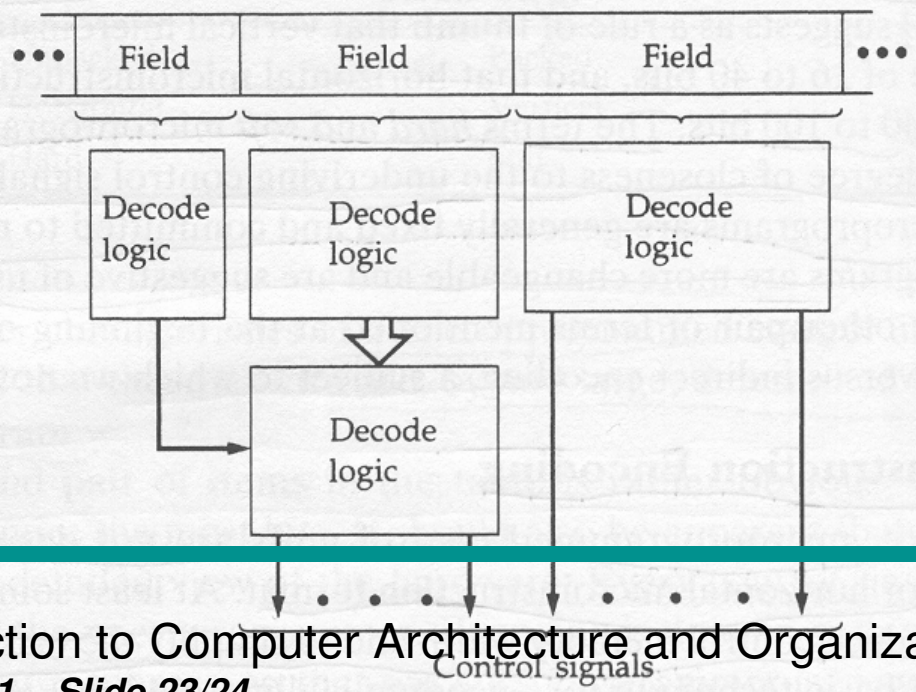
The Microinstruction Spectrum

Characteristics	
Unencoded	Highly encoded
Many bits	Few bits
Detailed view of hardware	Aggregated view of hardware
Difficult to program	Easy to program
Concurrency fully exploited	Concurrency not fully exploited
Little or no control logic	Complex control logic
Fast execution	Slow execution
Optimize performance	Optimize programming
Terminology	
Unpacked	Packed
Horizontal	Vertical
Hard	Soft

Microinstruction encoding



(a) Direct encoding



(b) Indirect encoding

Applications of Microprogramming

- Realizations of computers
- Emulation
- Operating system support
- Realization of special-purpose devices
- High-level language support
- Microdiagnostics