

Micro-programmed Control

Ch 17

Micro-instructions
Micro-programmed
Control Unit
Sequencing
Execution Characteristics
Course Summary

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Hardwired Control ⁽⁴⁾

- Complex
- Fast
- Difficult to design
- Difficult to modify
 - lots of optimization work done at implementation phase (after design)
 - all optimization work (I.e., most of the work?) must be redone after any changes to design

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Micro-programmed Control ⁽³⁾

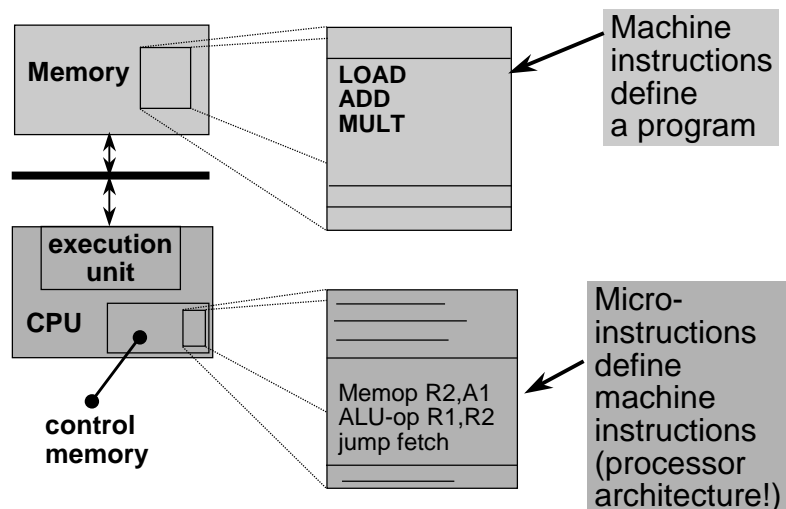
- Implement “execution engine” inside CPU
 - execute one micro-instruction at a time
- What to do now?
 - micro-instruction
 - control signals
 - stored in micro-instruction control memory
 - micro-program, firmware
- What to do next?
 - micro-instruction program counter
 - default (?): next micro-instruction
 - jumps or branches?

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Machine Instructions vs. Micro-instructions



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Machine Instructions vs. Micro-instructions ⁽²⁾

- Machine instruction fetch-execute cycle produces machine instructions to be executed at CPU
- Micro-instruction fetch-execute cycle produces control signals for data path

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Micro-program ⁽⁴⁾

- Stored in control memory
- ROM, PROM, EPROM
- One “subroutine” for each machine instruction
 - one or more micro-instructions
- Defines architecture
 - change instruction set?
 - ⇒ reload control memory

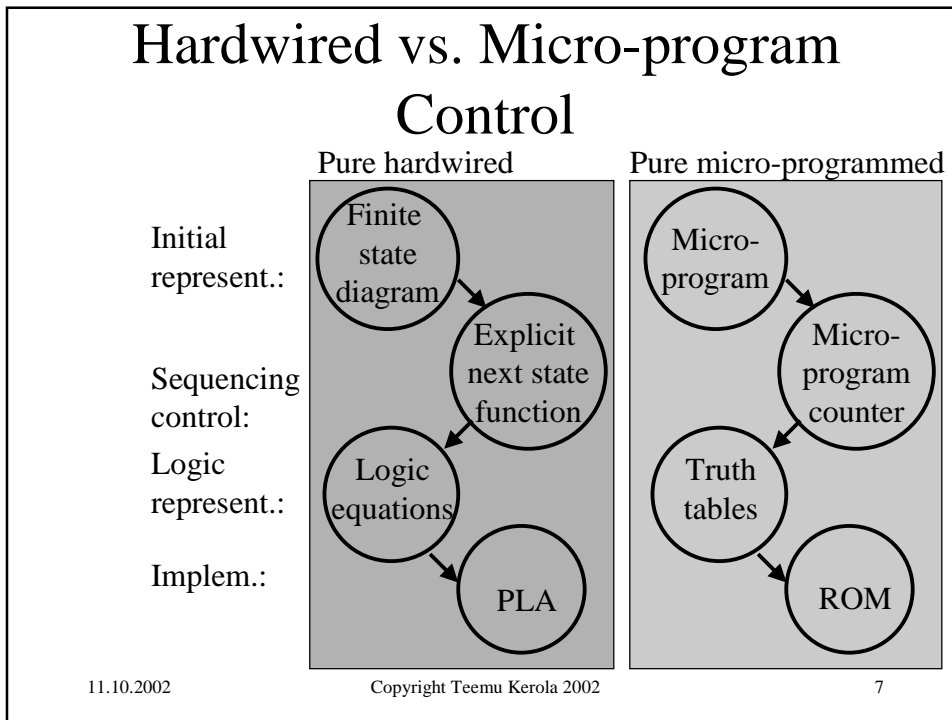
Fig. 17.2

(Fig. 15.2 [Stal99])

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Microcode (3)

- Horizontal micro-code (Fig. 15.1 (a) [Stal99])
 - control signals directly in micro-code Fig. 15.1 (a)
 - all control signals always there
 - lots of signals \Rightarrow many bits in micro-instruction
- Vertical micro-code (Fig. 15.1 (b) [Stal99])
 - each action encoded densely Fig. 17.1 (b)
 - actions need to be decoded to signals at execution time
 - takes less space but may be slower
- Each micro-instruction is also a conditional branch?

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Micro-programmed Control Unit ⁽⁴⁾

- Control Address Register
 - “micro-program PC”
- Control Memory
- Control Buffer Register
 - current micro-instruction
 - control signals
 - next address control
- Sequencing logic
 - select next value for Control Address Reg

Fig. 17.4

(Fig. 15.4 [Stal99])

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Micro-programming ⁽³⁾

- Simple design
- Flexible
 - adapt to changes in organization, timing, technology
 - make changes late in design cycle, or even in the field
- Very powerful instruction sets
 - use bigger control memory if needed
 - easy to have complex instruction sets
 - is this good?

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Micro-programming (2)

- **Generality**
 - multiple instruction sets on same machine
 - tailor instruction set to application?
- **Compatibility**
 - easy to be backward compatible in one family
 - many organizations, same instruction set

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Micro-programming (3)

- **Costly to implement**
 - need tools:
 - micro-program development environment
 - micro-program compiler
- **Slow**
 - micro-instruction interpreted at execution time
 - interpretation is internal to CPU
 - interpret one instruction at a time
- **Interpretation control with hardwired logic?**

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RISC vs. Micro-programming ⁽⁸⁾

- Simple instructions can execute at very high clock rate
- Compilers can produce micro-instructions
 - machine dependent optimization
- Use only simple instructions and addressing mode
- Keep “micro-code” in RAM instead of ROM
- no micro-instruction interpretation logic needed
- Fast access to “micro-code” in RAM via caching
- Skip instruction interpretation of a micro-program and simply compile directly into lowest language of machine?
- \Rightarrow Compile to “micro-code” and use hardwired control for RISC (e.g., Pentium II)

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Micro-program Sequencing ⁽³⁾

- Two address format Fig. 17.6 (Fig. 15.6 [Stal99])
 - most often need next micro-instruction address
 - waste of space to store it most of the time?
 - conditional branch address (Fig. 15.7 [Stal99])
- One address format Fig. 17.7
 - (Conditional) branch address
- Variable format
 - only branch micro-instructions have addresses
 - waste of time many times?

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Micro-instruction Explicit Address Generation

- Addresses explicitly present
 - Two-field
 - select one of them
 - Unconditional branch
 - jump to this one
 - Conditional branch
 - select this one or default

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Micro-instruction Implicit Address Generation

- Addresses not explicitly present
 - Mapping
 - map opcode in machine instruction into micro-instruction address (Fig. 15.9 [Stal99])
 - Addition Fig. 17.9
 - higher order bits directly from opcode
 - lower order bits based on current status and tag bits, or fields in current microinstruction
 - Residual Control
 - return from micro-program subroutine

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Micro-instruction Encoding

- Usually a compromise between pure horizontal and vertical formats

Fig. 17.11 (Fig. 15.11 [Stal99])

- optimize on space with encoding multiple signals into a set of fields
 - each field defines control signals for certain separate actions
 - mutually exclusive actions are encoded into the same field
- make design simpler by not using maximum encoding

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Micro-instruction Encoding (2)

- Functional encoding
 - each field controls some function
 - load accumulator
 - load ALU operands
 - compute next PC
- Resource encoding
 - each field controls some resource
 - ALU
 - memory

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Different Micro-instruction Sets for a specific "Simple Machine" ⁽³⁾

(Fig. 15.12 [Stal99])

- Micro-instruction types Fig. 17.12
 - 3 register transfers, 2 mem ops, 5 ALU ops, 3 seq. ops
- Vertical format

type	operation	reg
------	-----------	-----

 - 3 bits for type, 3 bits for operation (Fig. 15.12(a) [Stal99])
 - 2 bits for reg select (max 4 regs) Fig. 17.12 (a)
- Horizontal format

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 - 2 bits for reg transfers (3 ops + "none")
 - 2 bits for mem ops (2 ops + "none") Fig. 17.12 (b)
 - 2 bits for seq. ops (3 ops + "none") (Fig. 15.12(b) [Stal99])
 - 3 bits for ALU ops (5 ops + "none")
 - 2 bits for reg select + 8 bits for constant

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LSI-11 Single Board Processor



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LSI-11 (PDP-11) ⁽⁵⁾

- Three-chip single board processor
 - data chip
 - 26 8-bit regs
 - 8 16-bit general purpose regs,
 - PWS, MAR, MBR, ...
 - 8-bit ALU
 - (at least) 2 passes needed for 16-bit reg ops
 - control chip (Fig. 15.14 [Stal99])
 - control store chip (Fig. 17.14)
 - 22 bit wide control mem for micro-instructions
 - connected by micro-instruction bus (Fig. 17.13) (Fig. 15.13 [Stal99])

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LSI-11 Micro-instruction Set ⁽²⁾

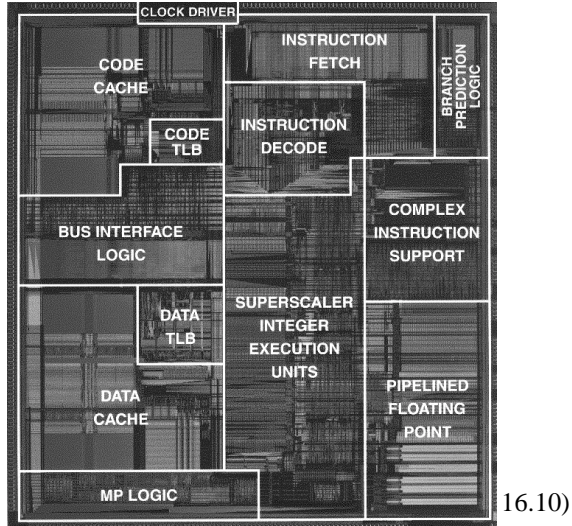
- Implements PDP-11 instruction set architecture for LSI-11 hardware
 - e.g., PDP-11 16 bit ALU vs. LSI-11 8-bit ALU
- 22 bit wide, extremely vertical set (Fig. 17.15) (Fig. 15.15 [Stal99])
 - 4 bits for special functions
 - 1 bit for testing interrupts
 - 1 bit for “micro-subroutine return”
 - 16 bits for variable format micro-ops
 - jump, cond. branch, literal ops, reg ops
 - ALU, logical, general, I/O ops (Table 17.5) (Tbl 15.5 [Stal99])

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-- End of Chapter 17 --
-- Micro-programmed Control --



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Summary ⁽¹¹⁾

- How clock signals cause instruction executions?
- Low level stuff
 - gates, basic circuits, registers, memory
- Cache
- Virtual memory & TLB
- ALU, Int & FP arithmetic's
- Instruction sets
- CPU structure & pipelining
- Branch prediction, limitations, hazards, issue
- RISC & superscalar processor
- IA-64 & Crusoe
- Hardwired & micro-controlled control

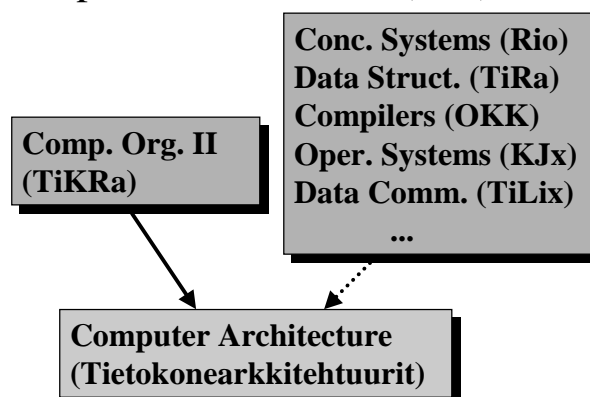
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Want to Know More?

- Read the text book completely
- 58070-8 Computer Architecture (4 cr)



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