Computer Organization & Architecture

Chapter 5 – Microprogrammed Control

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Content of this lecture

- Microprogrammed Control (See 5.7.2)
- Summary

Microprogrammed Control (1)

- It is possible to use a "software" approach, in which the desired setting of the control signals in each step is determined by a program stored in a special memory.

- Control Word (Microinstruction)

  - Suppose that n control signals are needed. Let each control signal be represented by a bit in an n-bit word, which is often referred to as a *control word* or a *microinstruction*.

- Microroutine (Microprogram)

  - A sequence of CWs corresponding to the control sequence of a machine instruction constitute the *microroutine* for that instruction.

Microprogrammed Control (2)

- Microprogram Memory or Control Store
  - The microprogram is stored on the processor chip in a small and fast memory called the *microprogram memory* or the *control store*.

- A processor instruction is implemented by a sequence of microinstructions that are placed in a control store.

Microprogrammed Control (3)
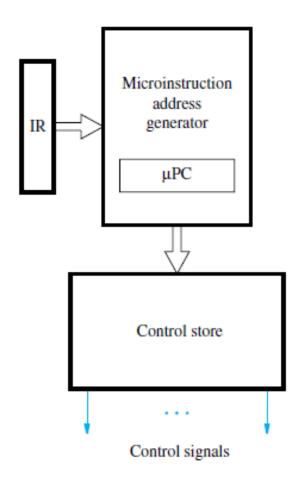
- **Microprogrammed Control Unit**

Figure 5.27   Microprogrammed control unit organization.

Microprogrammed Control (4)

- Microinstruction Encoding Schemes
  - Scheme1: Assigning one bit position to each control signal.
    - Drawbacks
      - Assigning individual bits to each control signal results in long microinstructions.
      - Only a few bits are set to 1 in any given microinstructions, so the available bit space is poorly used.

Microprogrammed Control (5)

- Microinstruction Encoding Schemes (ctd.)
  - Scheme2: Grouping signals into fields
    - Signals can be grouped so that all mutually exclusive signals are placed in the same group. Further natural groupings can be made for the remaining signals.
    - Advantage
      - Reduce the number of bits in each microinstruction.
    - Drawback
      - Require a little more decoding circuits.
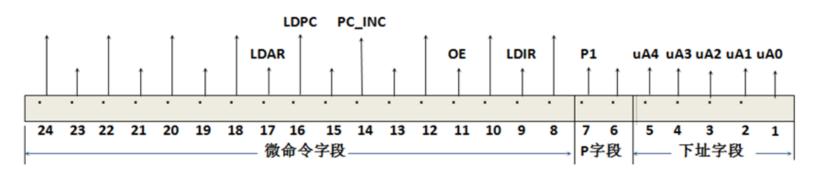
Microprogrammed Control (6)

- Microprogram Sequencing
  - uPC
    - A microroutine is entered by decoding the machine instruction into a starting address that is loaded into the uPC.
    - In most cases, the microinstructions are executed sequentially.
    - Some branching capability within the microprogram can be introduced through special branch microinstructions that specify the branch address.
    - Advantage: Standard software technique can be used in writing microprograms.
    - Disadvantage: It takes more time to carry out the required branch, so the execution time is longer.

Microprogrammed Control (7)

- Microprogram Sequencing (ctd.)
  - Microinstructions with Next-address Field
    - Include an address field as a part of every microinstruction to indicate the location of the next microinstruction to be fetched.
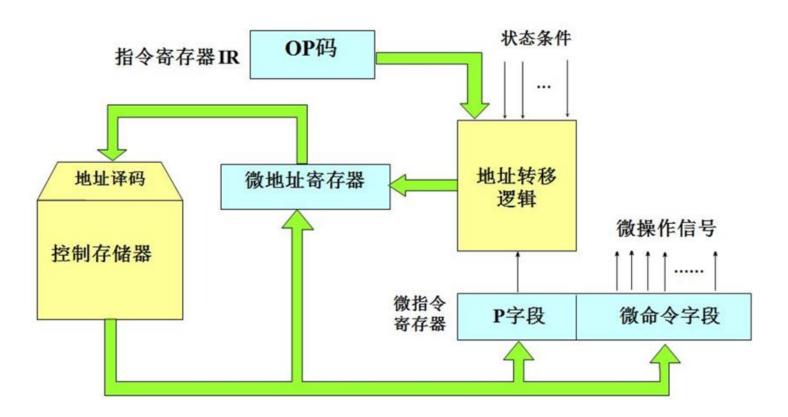
Microprogrammed Control (8)

- ## Microprogram Control Example (Lab4)
  - ### Microinstruction Format
    - 微指令字长 24 位，通过下址转移方式确定后续运行的微指令，即微指令的 1-5 位表示下一条微指令地址 [uA4, uA0]。
    - 微指令的 6-7 位留给判断字段 Px（其中 P2 位空缺），P1=1，表示本微指令是取指周期的微指令；P1=0，表示本微指令是执行周期的微指令。
    - 微指令的 8-24 位则是微命令字段，微命令即是数据通路中电平触发的微操作信号。某位置"1"，表示该位微操作信号有效；反之，置"0"则表示该位微操作信号无效。

Microprogrammed Control (9)

- Microprogram Control Example (ctd.)
  - Microprogrammed Control Unit
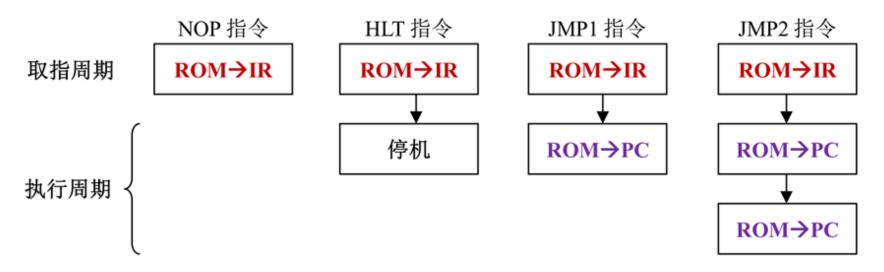
Microprogrammed Control (10)

- ## Microprogram Control Example (ctd.)
  - ☐ Machine Instructions

指令	OP 码 $I_7 I_6 I_5$	机器语言程序示例	指令功能说明
NOP	0 0 0	00000000; NOP	"空"指令，不执行任何操作
HLT	1 1 1	11100000; HLT	硬件停机
JMP1	0 0 1	00100000; JMP1 xxxxxxxx; addr1	直接寻址：程序跳转一次到地址 addr1 执行 addr1→PC;
JMP2	0 1 0	01000000; JMP2 xxxxxxxx; addr1	间接寻址：程序跳转二次到地址 addr2 执行 [addr1] = addr2, addr2 →PC;

Microprogrammed Control (11)

■ Microprogram Control Example (ctd.)

□ 指令周期示意图

	NOP 指令	HLT 指令	JMP1 指令	JMP2 指令
取指周期	**ROM→IR**	**ROM→IR**	**ROM→IR**	**ROM→IR**
执行周期		停机	**ROM→PC**	**ROM→PC**
				ROM→PC

■ 指令流（ROM->IR）是从存储器 PROGRAM 取出指令，经过总线 BUS 流向指令寄存器 IR。

■ 数据流（ROM->PC）是从存储器 PROGRAM 取出数据，经过总线 BUS 流向程序计数器 PC。

Microprogram Control Example (ctd.)

□ 指令流/数据流的微操作信号列表

		有效的微操作信号	功能
指令流 ROM→IR	T1	$\overline{OE}$, AR_CLK（LDAR）	PC→AR, ROM→BUS
	T2	$\overline{OE}$, IR_CLK (LDIR), PC_CLK (PC_INC)	BUS→IR, PC+1
数据流 ROM→PC	T1	$\overline{OE}$, $\overline{LDPC}$, AR_CLK (LDAR)	PC→AR, ROM→BUS
	T2	$\overline{OE}$, $\overline{LDPC}$, PC_CLK (PC_INC)	BUS→PC

■ 无论是指令流还是数据流，信息都是先从一个部件打到总线 BUS，再从总线 BUS打到另一个部件的过程。

■ 所以为了保证上述操作的先后次序，指令流和数据流内部都可以分为两个周期 T1 和 T2。

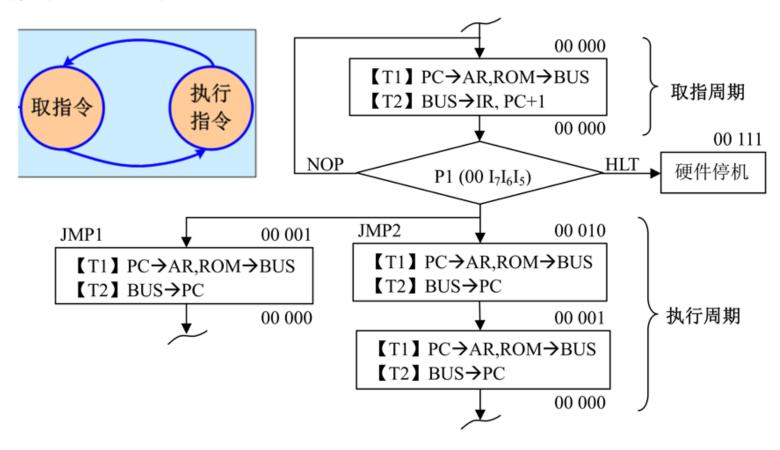# Microprogrammed Control (13)

■ Microprogram Control Example (ctd.)

□ 微指令代码表

Addr	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
00000	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0
00001	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
00010	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1
00111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Microprogrammed Control (14)

■ Microprogram Control Example (ctd.)

□ 微程序流程图

取指令 ⇄ 执行指令

【T1】PC→AR,ROM→BUS
【T2】BUS→IR, PC+1
00 000

00 000

取指周期

NOP   P1 (00 I₇I₆I₅)   HLT   00 111
硬件停机

JMP1   00 001
【T1】PC→AR,ROM→BUS
【T2】BUS→PC
00 000

JMP2   00 010
【T1】PC→AR,ROM→BUS
【T2】BUS→PC
00 001

【T1】PC→AR,ROM→BUS
【T2】BUS→PC
00 000

执行周期

Benefits of Microprogramming

- The decoders and sequencing logic unit of a micro-programmed control unit are very simple pieces of logic, compared to the hardwired control unit.

- Simpler design means the control unit is cheaper and less error-prone to implement.

- It is also flexible as changes could be easily made to the design.

Exercise (1)

- 1. In a microprogram-control computer, the microinstructions are stored in a memory called the (   ).
  - ☐ A. direct memory
  - ☐ B. physical memory
  - ☐ C. virtual memory
  - ☐ D. control store

Exercise (2)

- 2. Micro-programmed control unit is (   ) than hardwired but (   ).
    - ☐ A. cheaper, more error prone
    - ☐ B. faster, more error prone
    - ☐ C. less error prone, slower
    - ☐ D. faster, harder to change

Exercise (3)

- 3.In microprogram-controlled machines, the relationship between the machine instruction and the microinstruction is (   ) .

  - ☐ A. a machine instruction is executed by a microinstruction

  - ☐ B. a microinstruciton is composed of several machine instructions

  - ☐ C. a machine instruction is interpreted by a microroutine composed of microinstructions

  - ☐ D. a microroutine is executed by a machine instruction

Summary

- 知识点：Microprogram Control Unit
  - Principle of microprogram control: Figure 5.27
  - Terminologies
    - Control word : A *control word* is a word whose individual bits represent the various
    - Microprogram: A sequence of CWs corresponding to the control sequence of a machine instruction constitute the *microroutine* for that instruction.
    - Control store: The microinstruction for all instructions in the instruction set of a computer are stored in a special memory called *control store*.