Chapter 4: Microprogrammed and Hardwired Control Unit

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Hardwired control unit

- Hardwired control units are generally faster than microprogrammed designs.

- In hardwired control, we will saw how all the control signals required inside the CPU can be generated using a state counter and a PLA circuit.

A microprogrammed control unit

- A microprogrammed control unit is a relatively simple logic circuit that is capable of:

1. sequencing through microinstructions
2. generating control signals to execute each microinstruction.

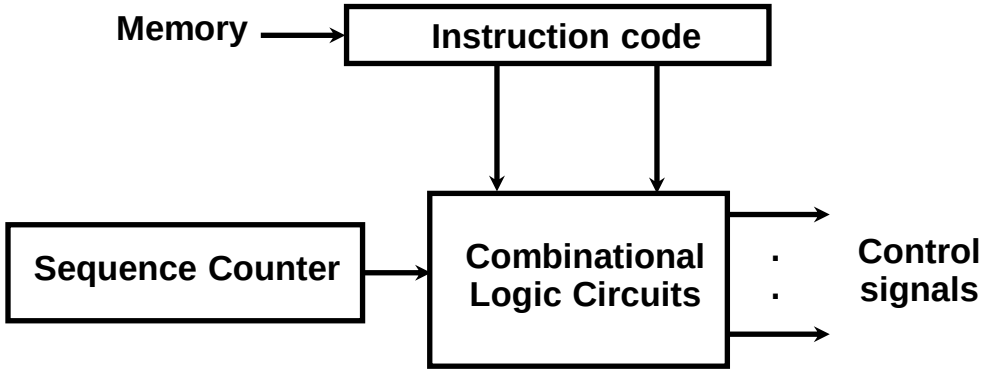
some Important Terms

- **Control Word :** A control word is a word whose individual bits represent various control signals.
- **Micro-routine :** A sequence of control words corresponding to the control sequence of a machine instruction constitutes the micro-routine for that instruction.

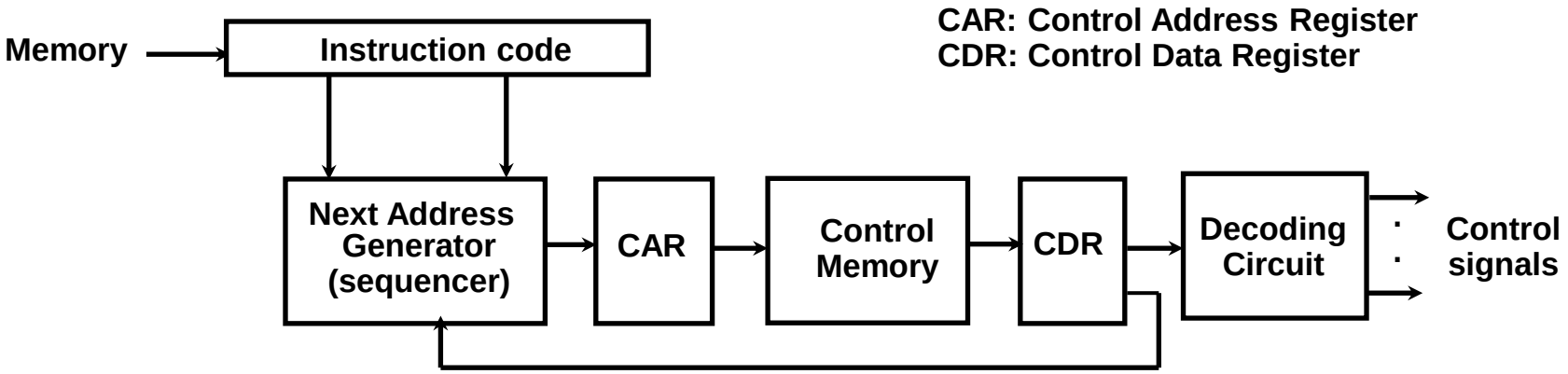
- **Microinstruction :** Individual control words in this micro-routine are referred to as microinstructions.
- **Micro-program :** A sequence of micro-instructions is called a micro-program, which is stored in a ROM or RAM called a Control Memory (CM).
- **Control Store :** the micro-routines for all instructions in the instruction set of a computer are stored in a special memory called the Control Store.

Control Unit Implementation

- Hardwired



- Microprogrammed



Microprogrammed Control Unit

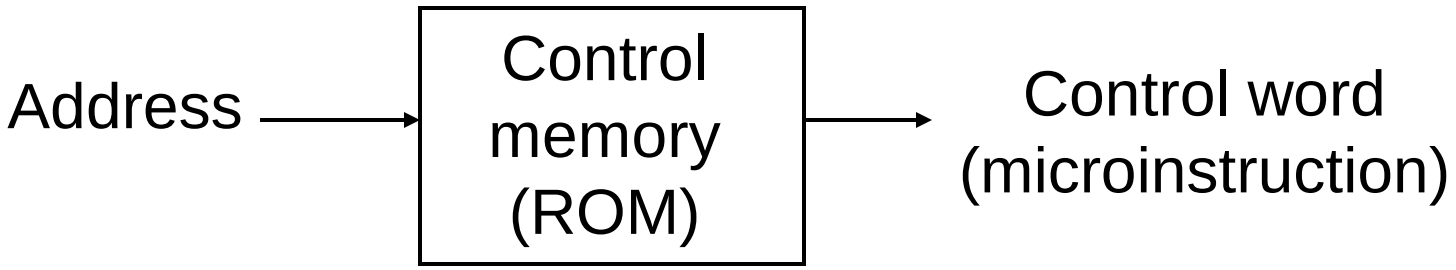
- Control signals
  - Group of bits used to select paths in multiplexers, decoders, arithmetic logic units
- Control variables
  - Binary variables specify microoperations
    - Certain microoperations initiated while others idle
- Control word
  - String of 1’s and 0’s represent control variables

Microprogrammed Control Unit

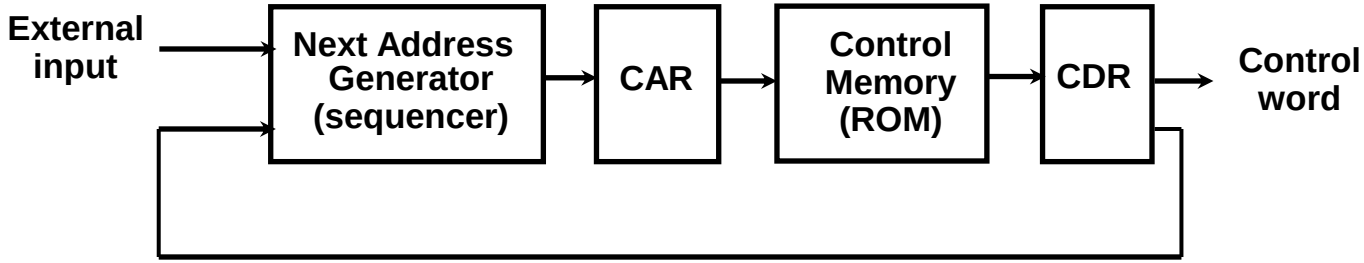
- Control memory
  - Memory contains control words
- Microinstructions
  - Control words stored in control memory
  - Specify control signals for execution of micro-operations
- Microprogram
  - Sequence of microinstructions

Control Memory

- Read-only memory (ROM)
- Content of word in ROM at given address specifies microinstruction
- Each computer instruction initiates series of microinstructions (microprogram) in control memory
- These microinstructions generate microoperations to
  - Fetch instruction from main memory
  - Evaluate effective address
  - Execute operation specified by instruction
  - Return control to fetch phase for next instruction



Microprogrammed Control Organization



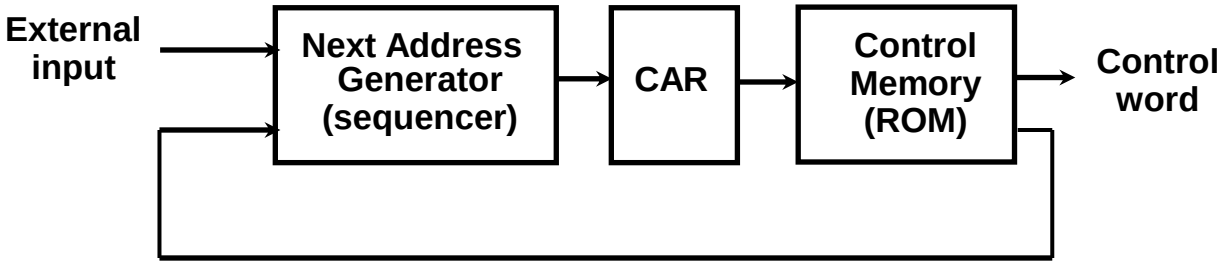
- Control memory
  - Contains microprograms (set of microinstructions)
  - Microinstruction contains
    - Bits initiate microoperations
    - Bits determine address of next microinstruction
- Control address register (CAR)
  - Specifies address of next microinstruction

Microprogrammed Control Organization

- Next address generator (microprogram sequencer)
  - Determines address sequence for control memory
- Microprogram sequencer functions
  - Increment CAR by one
  - Transfer external address into CAR
  - Load initial address into CAR to start control operations

Microprogrammed Control Organization

- Control data register (CDR)- or pipeline register
  - Holds microinstruction read from control memory
  - Allows execution of microoperations specified by control word simultaneously with generation of next microinstruction
- Control unit can operate without CDR



Microprogram Routines

- Routine
  - Group of microinstructions stored in control memory
- Each computer instruction has its own microprogram routine to generate micro-operations that execute the instruction

Microprogram Routines

- Subroutine
  - Sequence of microinstructions used by other routines to accomplish particular task
- Example
  - Subroutine to generate effective address of operand for memory reference instruction
- Subroutine register (SBR)
  - Stores return address during subroutine call

Conditional Branching

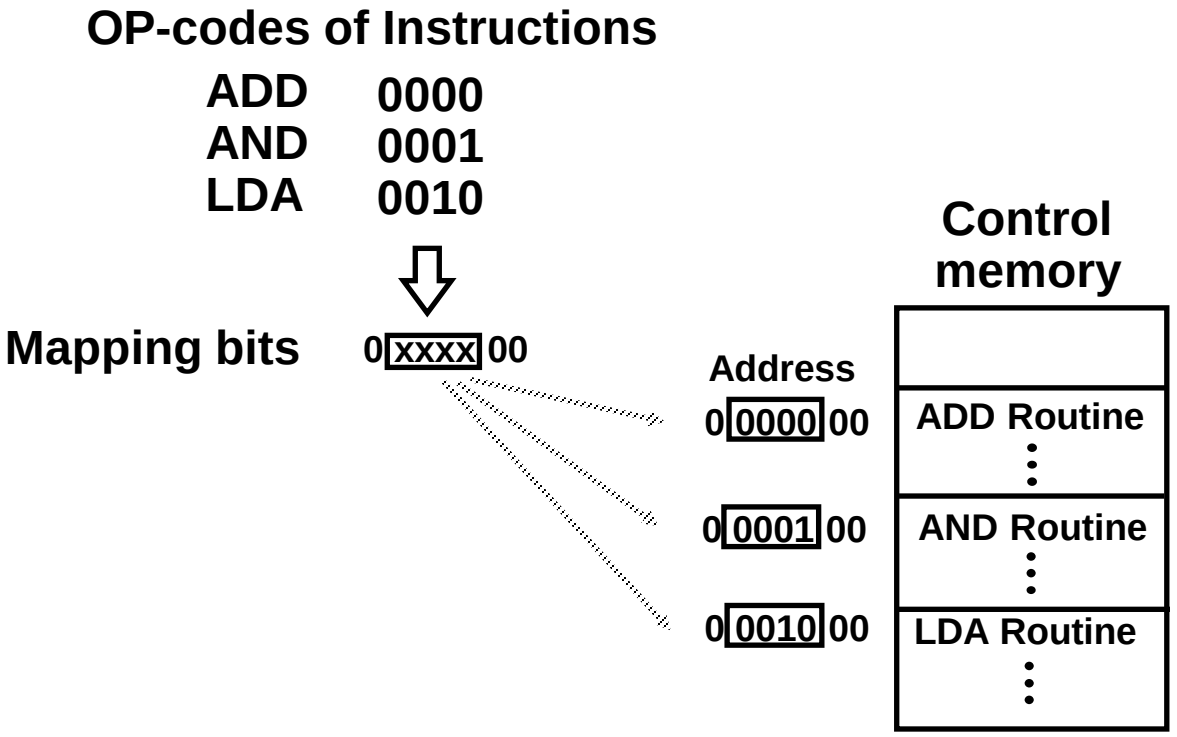
- Branching from one routine to another depends on status bit conditions
- Status bits provide parameter info such as
  - Carry-out of adder
  - Sign bit of number
  - Mode bits of instruction
- Info in status bits can be tested and actions initiated based on their conditions: 1 or 0
- Unconditional branch
  - Fix value of status bit to 1

Mapping of Instruction

- Each computer instruction has its own microprogram routine stored in a given location of the control memory
- Mapping
  - Transformation from instruction code bits to address in control memory where routine is located

Mapping of Instruction

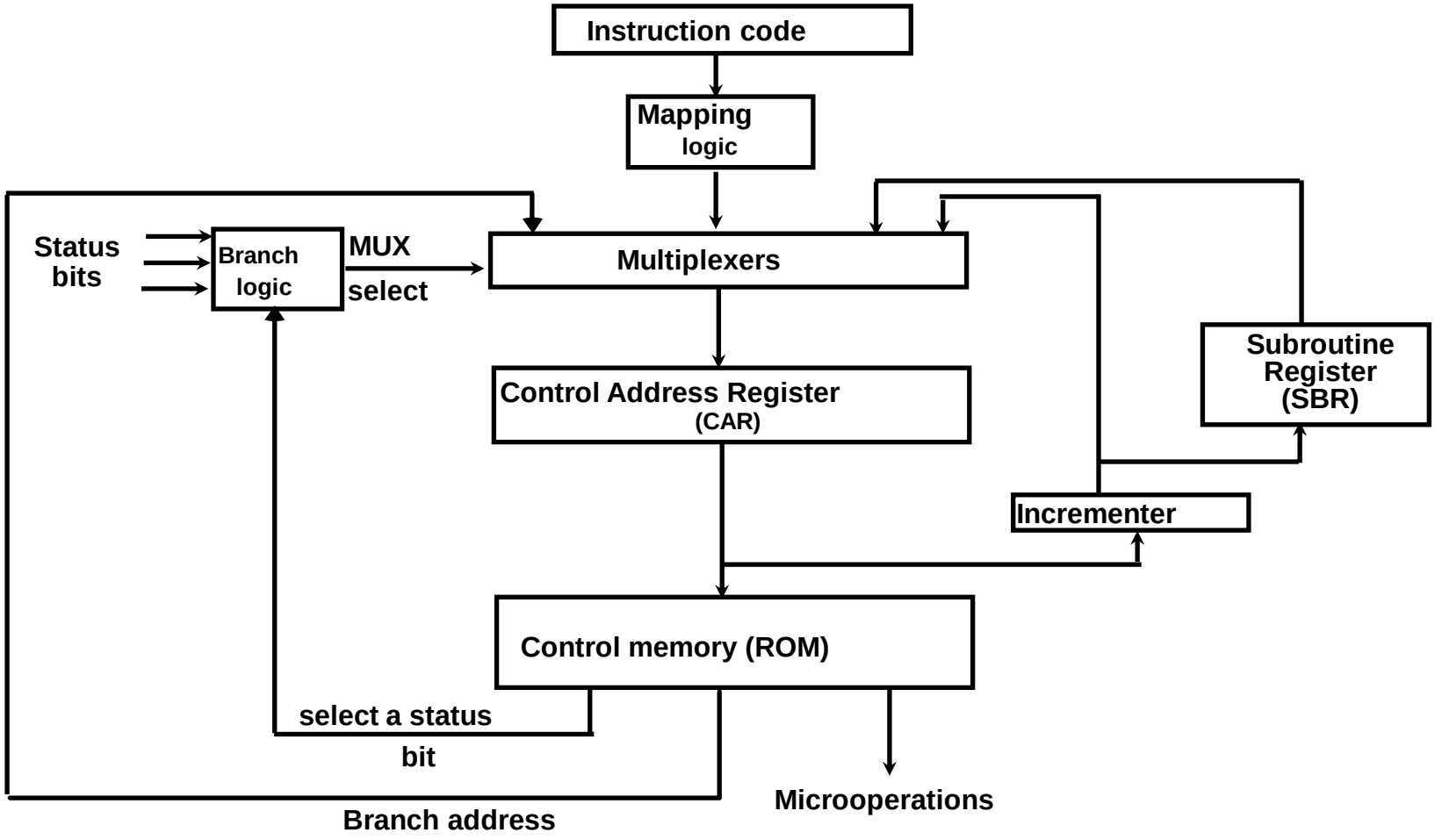
- Example
  - Mapping 4-bit operation code to 7-bit address



Address Sequencing

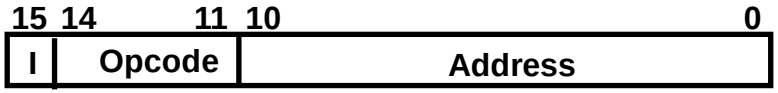
- Address sequencing capabilities required in control unit
  - Incrementing CAR
  - Unconditional or conditional branch, depending on status bit conditions
  - Mapping from bits of instruction to address for control memory
  - Facility for subroutine call and return

Address Sequencing

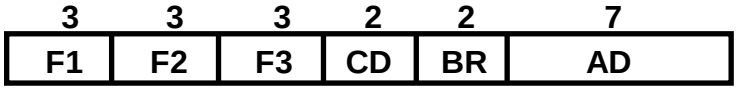


Microprogram Example

Computer instruction format



Microinstruction Format



F1, F2, F3: Microoperation fields
CD: Condition for branching
BR: Branch field
AD: Address field

Hardwired control unit characteristics

- Hardwired control unit generates the control signals needed for the processor using logic circuits
- Hardwired control unit is faster when compared to microprogrammed control unit as the required control signals are generated with the help of hardware's
- Difficult to modify as the control signals that need to be generated are hard wired
- More costlier as everything has to be realized in terms of logic gates
- It cannot handle complex instructions as the circuit design for it becomes complex
- Only limited number of instructions are used due to the hardware implementation
- Used in computer that makes use of Reduced Instruction Set Computers(RISC)

Microprogrammed control unit characteristics

- Microprogrammed control unit generates the control signals with the help of micro instructions stored in control memory
- This is slower than the other as micro instructions are used for generating signals here
- Easy to modify as the modification need to be done only at the instruction level
- Less costlier than hardwired control as only micro instructions are used for generating control signals
- It can handle complex instructions
- Control signals for many instructions can be generated
- Used in computer that makes use of Complex Instruction Set Computers(CISC)

Application of microprogrammed

- Realization of computers
- Emulation
- Operating system support
- Realization of special purpose devices
- High-level language support
- Micro diagnostic