Timing & Control

CONTROL UNIT

- CPU is partitioned into *Arithmetic Logic Unit (ALU)* and *Control Unit (CU)*.

- The function of control unit is to generate relevant timing and control signals to all operations in the computer.

- It controls the flow of data between the processor and memory and peripherals

FUNCTIONS OF CONTROL UNIT

- The control unit directs the entire computer system to carry out stored program instructions.
- The control unit must communicate with both the arithmetic logic unit (ALU) and main memory.
- The control unit instructs the arithmetic logic unit that which logical or arithmetic operation is to be performed.
- The control unit co-ordinates the activities of the other two units as well as all peripherals and auxiliary storage devices linked to the computer.

DESIGN OF CONTROL UNIT

Control unit generates control signals using one of the two organizations:

- Hardwired Control Unit
- Micro-programmed Control Unit

HARDWIRED CONTROL UNIT

- It is implemented as logic circuits (gates, flip-flops, decoders etc.) in the hardware.
- This organization is very complicated if we have a large control unit.
- In this organization, if the design has to be modified or changed, requires changes in the wiring among the various components. Thus the modification of all the combinational circuits may be very difficult.

HARDWIRED CONTROL UNIT

ADVANTAGES

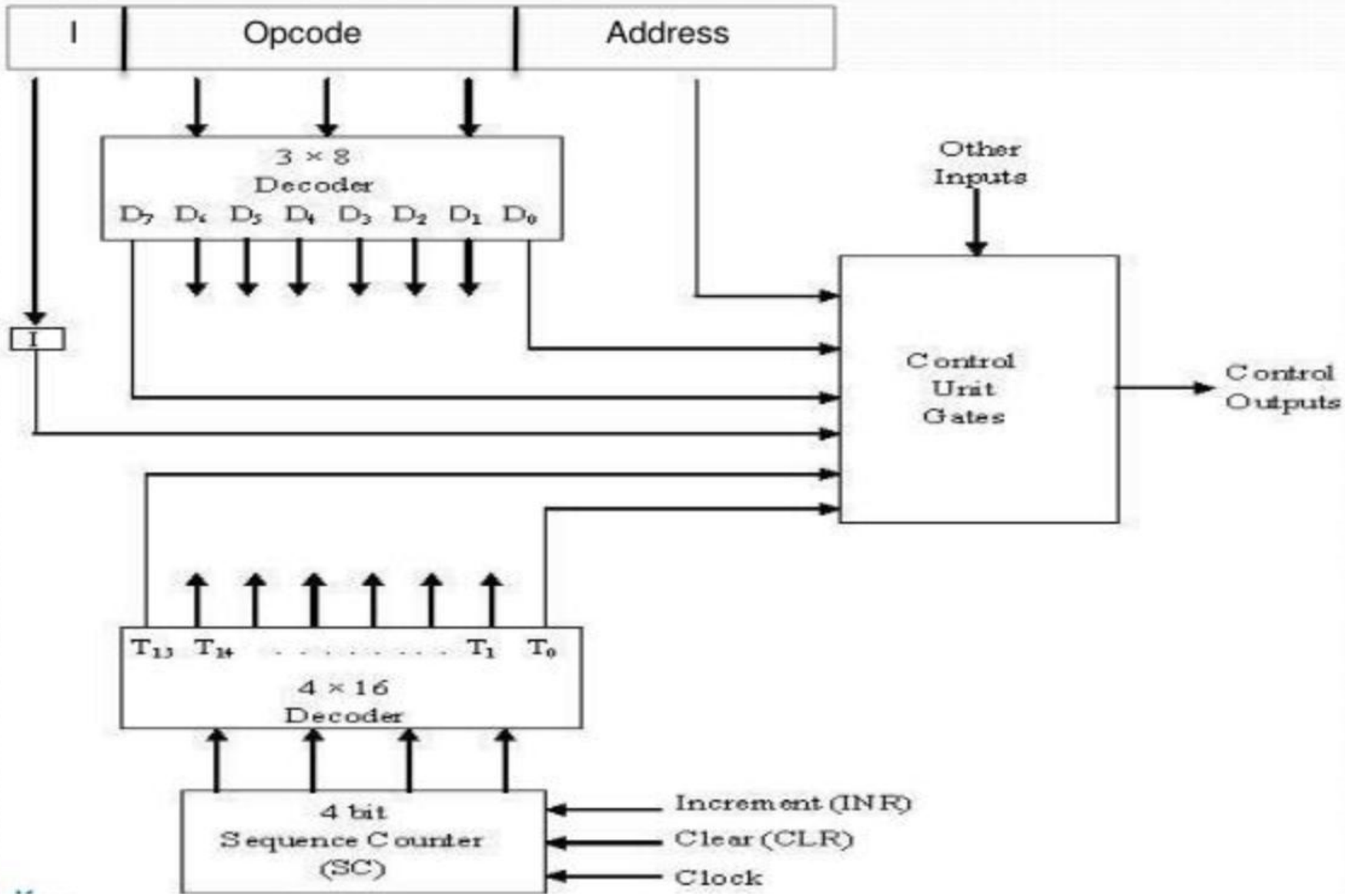
- Hardwired Control Unit is fast because control signals are generated by combinational circuits.
- The delay in generation of control signals depends upon the number of gates.

HARDWIRED CONTROL UNIT

DISADVANTAGES

- More is the control signals required by CPU; more complex will be the design of control unit.
- Modifications in control signal are very difficult. That means it requires rearranging of wires in the hardware circuit.
- It is difficult to correct mistake in original design or adding new feature in existing design of control unit.

ARCHITECTURE OF HARDWIRED CONTROL UNIT



HARDWIRED CONTROL UNIT

Control unit consist of a:

- Instruction Register
- Number of Control Logic Gates,
- Two Decoders
- 4-bit Sequence Counter

HARDWIRED CONTROL UNIT

- An instruction read from memory is placed in the instruction register (IR).
- The instruction register is divided into three parts: the I bit, operation code, and address part.
- First 12-bits (0-11) to specify an address, next 3-bits specify the operation code (opcode) field of the instruction and last left most bit specify the addressing mode I.

  I = 0 for direct address

  I = 1 for indirect address

HARDWIRED CONTROL UNIT

- First 12-bits (0-11) are applied to the control logic gates.
- The operation code bits (12 – 14) are decoded with a 3 x 8 decoder.
- The eight outputs (D_0 through D_7) from a decoder goes to the control logic gates to perform specific operation.
- Last bit 15 is transferred to a I flip-flop designated by symbol I.

HARDWIRED CONTROL UNIT

- The 4-bit sequence counter SC can count in binary from 0 through 15.
- The counter output is decoded into 16 timing pulses T_0 through T_{15}.
- The sequence counter can be incremented by INR input or clear by CLR input synchronously.

HARDWIRED CONTROL UNIT

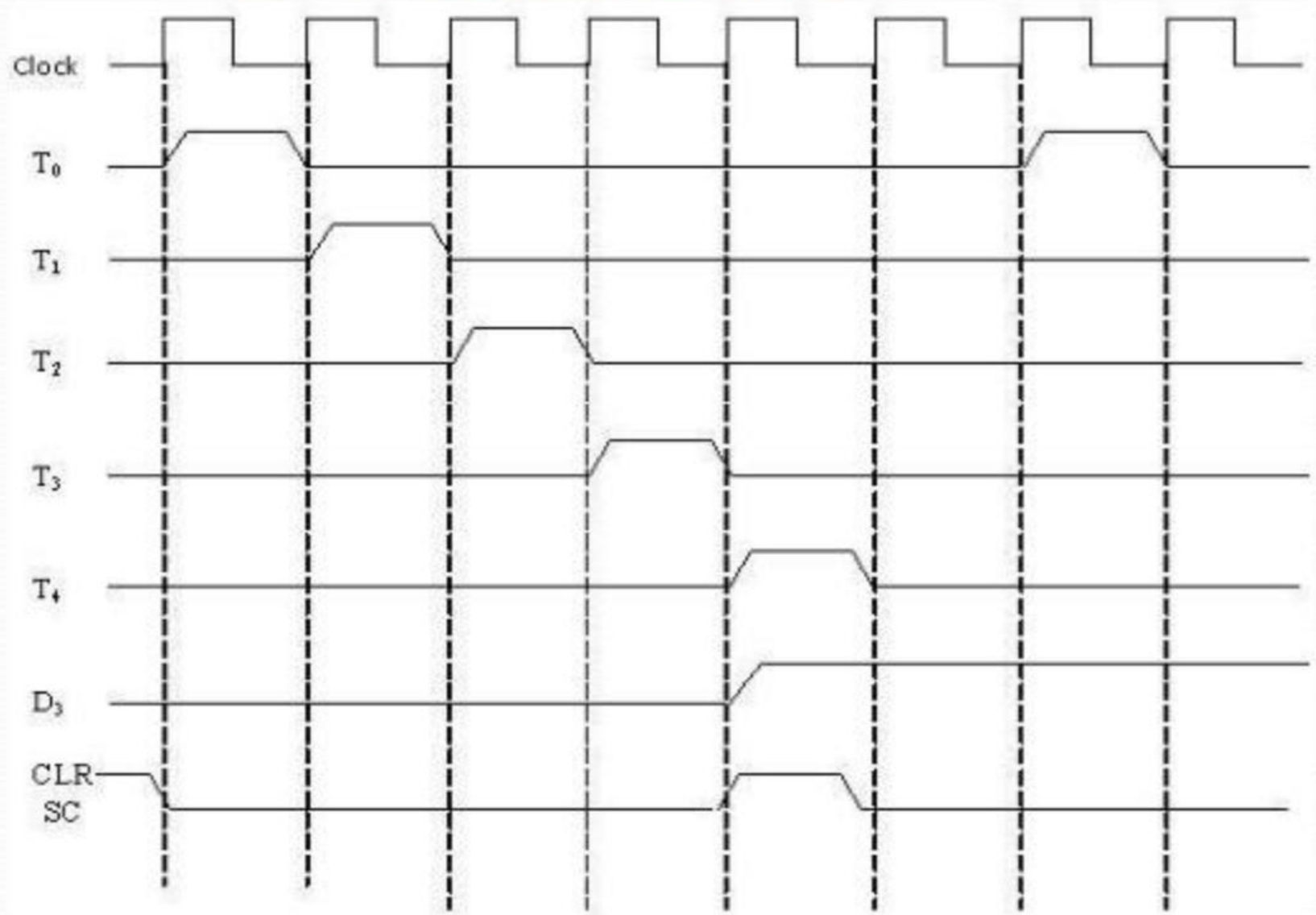
For example:

Consider the case where SC is incremented to provide timing signals $T_0, T_1, T_2, T_3,$ and T_4 in sequence. At time T_4, SC is cleared to 0 if decoder output D_3 is active. This is expressed symbolically by the statement:

$$D_3 T_4 : \quad SC \leftarrow 0$$

- The timing diagram shows the time relationship of the control signals.

TIMING DIAGRAM



MICRO-PROGRAMMED CONTROL UNIT

- A micro-programmed control unit is implemented using programming approach. A sequence of micro-operations are carried out by executing a program consisting of micro-instructions.
- Micro-program, consisting of micro-instructions is stored in the control memory of the control unit.
- Execution of a micro-instruction is responsible for generation of a set of control signals.

MICRO-PROGRAMMED CONTROL UNIT

- A **micro-instruction** consists of:
  - One or more micro-operations to be executed.
  - Address of next microinstruction to be executed.

Micro-Operations: The operations performed on the data stored inside the registers are called *micro-operations*.

- **Micro-Programs:** Microprogramming is the concept for generating control signals using programs. These programs are called *micro-programs*.

MICRO-PROGRAMMED CONTROL UNIT

- **Micro-Instructions:** The instructions that make micro-program are called *micro-instructions*.
- **Micro-Code:** Micro-program is a group of micro-instructions. The micro-program can also be termed as *micro-code*.
- **Control Memory:** Micro-programs are stored in the read only memory (ROM). That memory is called *control memory*.

MICRO-PROGRAMMED CONTROL UNIT

ADVANTAGES

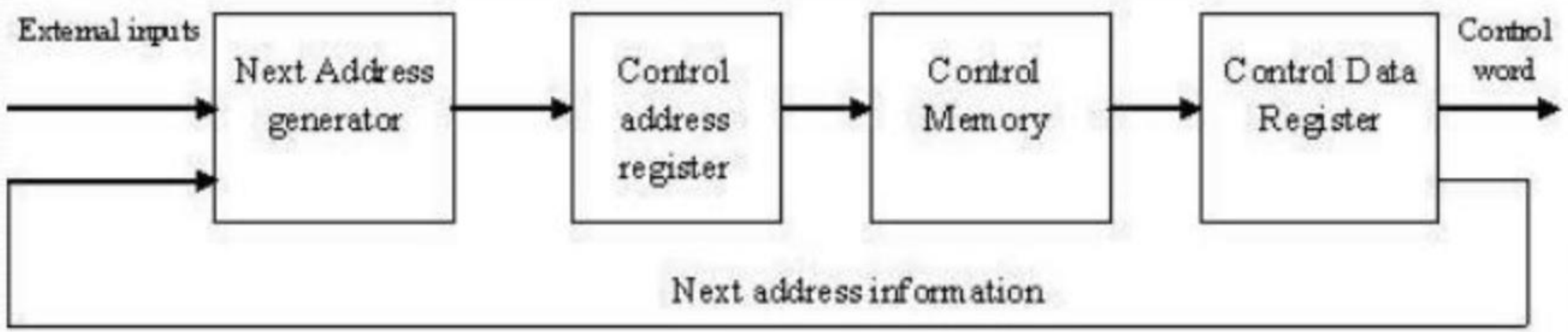
- The design of micro-program control unit is less complex because micro-programs are implemented using software routines.
- The micro-programmed control unit is more flexible because design modifications, correction and enhancement is easily possible.
- The new or modified instruction set of CPU can be easily implemented by simply rewriting or modifying the contents of control memory.
- The fault can be easily diagnosed in the micro-program control unit using diagnostics tools by maintaining the contents of flags, registers and counters.

MICRO-PROGRAMMED CONTROL UNIT

DISADVANTAGES

- The micro-program control unit is slower than hardwired control unit. That means to execute an instruction in micro-program control unit requires more time.
- The micro-program control unit is expensive than hardwired control unit in case of limited hardware resources.
- The design duration of micro-program control unit is more than hardwired control unit for smaller CPU.

ARCHITECTURE OF MICRO-PROGRAMMED CONTROL UNIT



ARCHITECTURE OF MICRO-PROGRAMMED CONTROL UNIT

- The address of micro-instruction that is to be executed is stored in the control address register (CAR).
- Micro-instruction corresponding to the address stored in CAR is fetched from control memory and is stored in the control data register (CDR).
- This micro-instruction contains control word to execute one or more micro-operations.
- After the execution of all micro-operations of micro-instruction, the address of next micro-instruction is located.

COMPARISON BETWEEN HARDWIRED AND MICRO-PROGRAMMED CONTROL UNIT

Attributes	Hardwired Control	Micro-programmed Control
Speed	Fast	Slow
Cost of Implementation	More	Cheaper
Flexibility	Not flexible, difficult to modify for new instruction	Flexible, new instructions can easily be added
Ability to Handle Complex Instructions	Difficult	Easier
Decoding	Complex	Easy
Applications	RISC Microprocessor	CISC Microprocessor
Instruction Set Size	Small	Large
Control Memory	Absent	Present
Chip Area Required	Less	More