Computer Architecture

Control Unit Operation

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Reference Books

- Computer Organization and Architecture: Designing for Performance- William Stallings (8^{th} Edition) (CH-15)
  - Any later edition is fine

Functional Requirements of Control Unit

- Those functions that the control unit must perform.
- Control unit characterization:
  1. Define the basic elements of the processor.
  2. Describe the micro-operations that the processor performs.
  3. Determine the functions that the control unit must perform to cause the micro-operations to be performed.

1. Basic functional elements of the processor:
   - **ALU**: Functional essence of the computer.
   - **Registers**: Internal storage of processor. Also used for PSW.
   - **Internal data paths**: Move data between registers and ALU.
   - **External data paths**: Registers to memory and I/O module.
   - **Control unit**: Causes operations to happen within processor.
2. Micro-operations categories:
   - Data transfer from one register to another.
   - Data transfer from a register to an external interface.
   - Data transfer from an external interface to a register.
   - An arithmetic or logic operation using registers for I/O.

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3. The control unit performs two basic tasks using control signals:
   - **Sequencing:** Sequencing micro-operations based on the program.
   - **Execution:** Causes micro-operations to be performed.

Control Signals:

- For control unit to perform tasks, it must have inputs that allow to determine the state of the system and outputs that allow to control the behavior of the system.
- These are the external specifications of the control unit.
- Internally, the control unit must have the logic required to perform its sequencing and execution functions.

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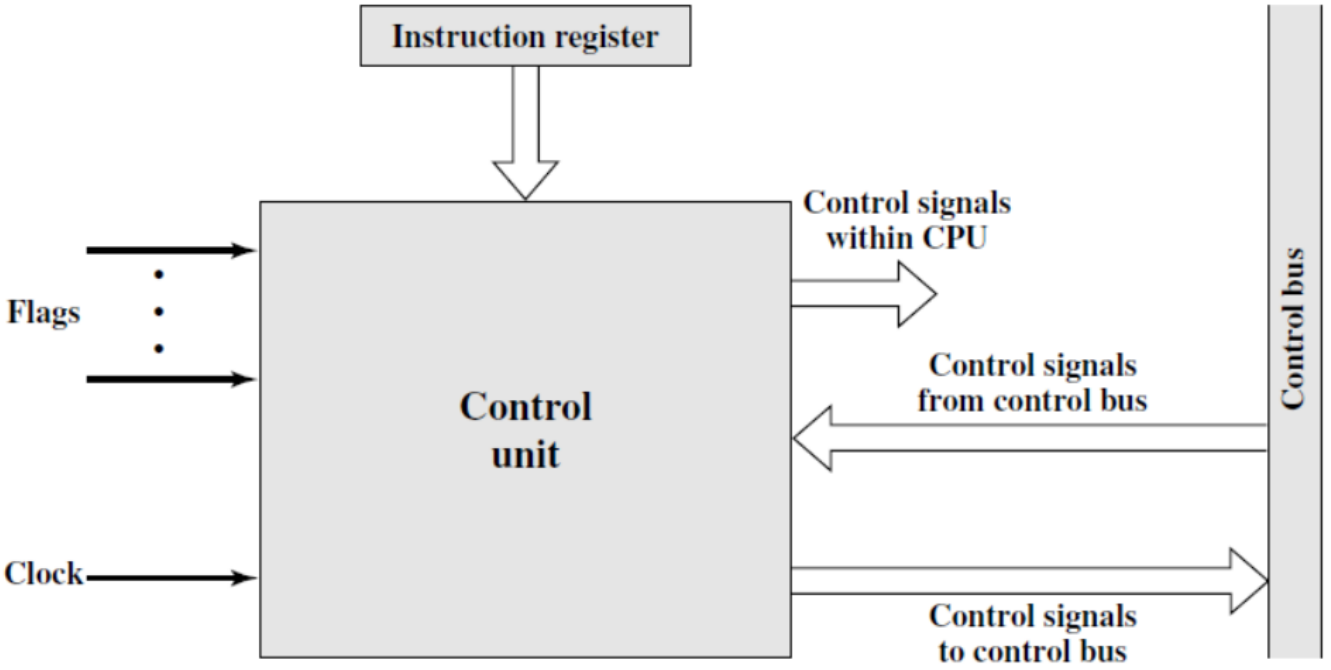

Block Diagram of the Control Unit

- This figure is a general model of control unit, showing all of its inputs and outputs.
- Inputs are:
  - Clock: For keeping time. One **μ**-operation per clock (Cycle time).
  - IR: Opcode & addressing mode of current instruction.
  - Flags: Status of processor & outcome of previous ALU operation.
  - Control signals from control bus.

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- Outputs are:
  - Control signals within the processor: Two types:
    - Those cause data to be moved from one register to another.
    - Those activate specific ALU functions.
  - Control signals to control bus: Two types:
    - Control signals to memory.
    - Control signals to I/O modules.

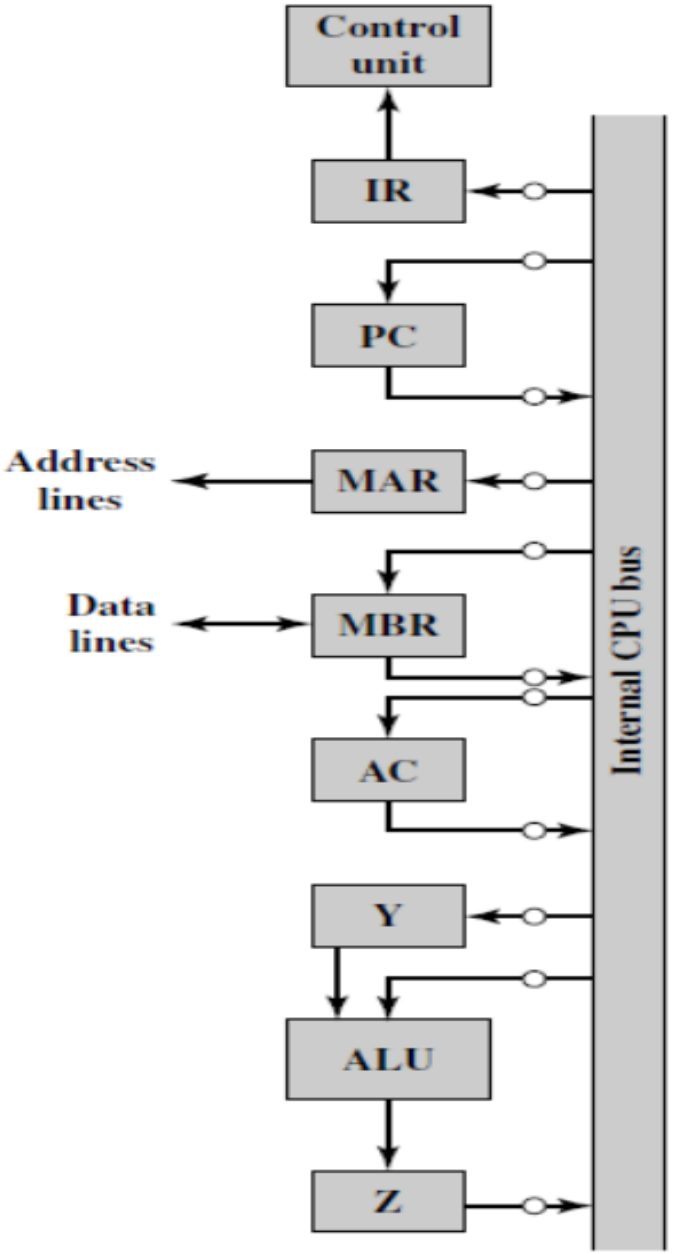
- So, three types of control signals are used:
  - Those activate an ALU function.
  - Those activate data-path.
  - Those are signals on the external system bus or other interfaces.
- All the signals are applied directly as binary inputs to individual logic gates.

Consider again the fetch cycle Example:

- The control unit (CU) keeps track of where it is in the instruction cycle.
- Lets consider a given point, when CU knows that fetch cycle is to be performed next.
- 1st step: Transfer contents of PC to MAR. CU does this by activating the control signal that opens gates between the bits of the PC and bits of the MAR.
- 2nd step: Read word from memory into MBR & increment PC. CU does this by sending following control signals simultaneously:
  - A control signal that opens gates, allowing the content of MAR onto the address bus.
  - A memory read control signal on the control bus.
  - A control signal that opens gates, allowing the contents of the data bus to be stored in MBR.
  - Control signals to logic that add 1 to the contents of PC and store result back to the PC.
- 3rd step: Transfer contents between MBR & IR. CU sends a control signal that opens gate between MBR & IR.

Internal Processor Organization

- Following figure illustrates the structure of a CPU with internal-bus.
- A single internal bus connects the ALU & all processor registers.
- Gates & control signals are provided for movement of data onto & off the bus from each register.
- Additional control signals control data transfer to & from the system bus & the operation of the ALU.
- Two new registers Y & Z are added to the organization.
- These are needed for the proper operation of the ALU.
- Y provides temporary storage for inputs.
- Z provide temporary storage for outputs.



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- With this arrangement, an operation to add a value from memory to the AC would have the following steps:
  - T1: MAR ← (IR (Address))
  - T2: MBR ← Memory
  - T3: Y ← (MBR)
  - T4: Z ← (AC) + (Y)
  - T5: AC ← (Z)

Implementation of Control Unit

- For the implementation of the control unit, various techniques have been used, which falls under two categories:
- **Hardware Implementation:** The control unit is essentially a state machine circuit. Its input logic signals are transferred into a set of output logic signals, which are the control signals.
- **Microprogrammed Implementation:**
  - An alternative to hardware implementation, in which the logic of the control unit is specified by a microprogram.
  - A microprogram consists of a sequence of instructions in a microprogramming language.
  - That are very simple instructions that specify micro-operations.
  - A microproammed control unit is capable:
    - Sequencing through micro-instructions.
    - Generating control signals to execute each instructions.

Practice Problems

- Problems: 15.1, 15.2, 15.3, 15.4, 15.5

Thank you!