UNIT – IV

CONTROL DESIGN — BASIC CONCEPTS

Q.1. Differentiate between a microprocessor and a microprogram. Is it possible to design a microprocessor without a microprogram? Explain. [UP Tech 2008-2009]

Ans. A microprocessor is a small size CPU. We can also say that it is a computer on a chip whereas, microprogram is a program for a sequence of microoperations.

It is possible to design a microprocessor without a microprogram. The microprocessor can be designed with the help of hardwired technique. When control organization is implemented with the help digital logic like gates, flip-flop, decoders then it is called hard wired control unit organization. In this organization if there is any change in the design then wiring between various components is also to be modified. The control unit of a microprocessor can be hardwired or microprogrammed, depending on the specific design. Most computers based on RISC (reduced instruction set computer) uses hardwired control rather than microprogrammed.

Q.2. How does control unit of a computer function? Explain with the help of a block diagram. [UP Tech 2004-2005]

Ans.

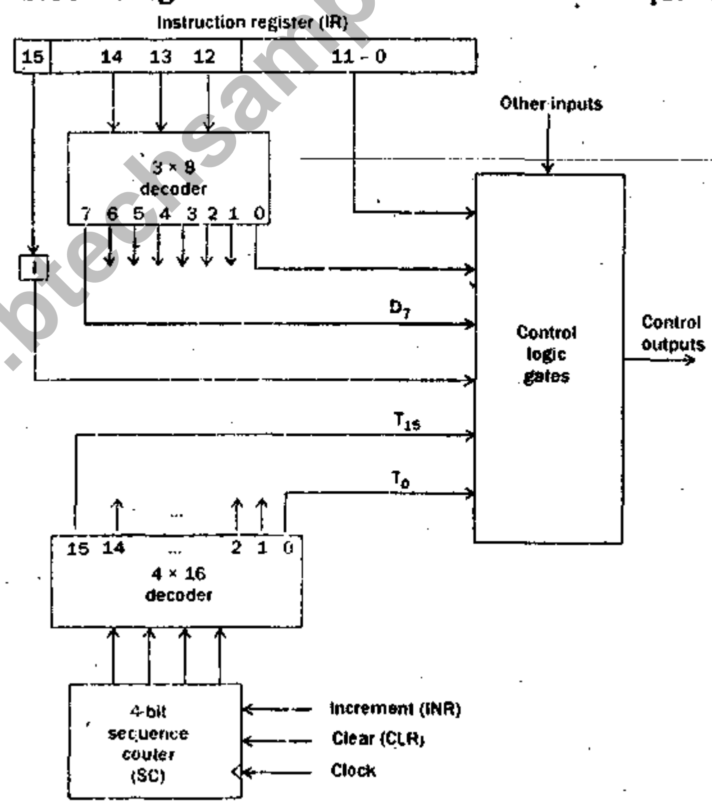

Fig. *Control unit of basic computer*

It consists of two decoders (3*8 decoder and 4*16 decoder), a sequence counter and control logic gates. An instruction register (IR) is also used. An instruction read from the memory is placed in IR. An instruction is divided in three parts: I bit, operation code, bits 0-11. 3* 8 decoder has three inputs and 8 outputs. Its three inputs come from instruction register. The operation code is present in bits 12-14, which is decoded by 3*8 decoder. Decoder decodes the Opcode (12-14) and result is applied to control logic gates. Another decoder which is used is 4*16 decoder. It has 4 inputs and 16 outputs. Its inputs come from sequence counter. In turn 4 *16 decoder decodes it and produces 16 timing signals T0-T15 which are applied to the control logic gates. A 4-bit sequence counter is used. Sequencer can be incremented and it cab be cleared. It produces 4 bit output. The output of sequence counter is applied to 4*16 decoder. In instruction register the operation code is present in bits 12-14, which is decoded by 3*8 decoder. Bits 0-11 are applied to control logic gates. Bit 15 is applied to flip-flop I.

The sequence counter responds to the positive transition of the clock. First positive transition of the clock clears SC to 0, which will activate T0 signal coming out of decoder. SC is incremented by one after each clock pulse. Hence timing sequence T1, T2, T3 .... is generated. A memory read or write cycle will be initiated with the rising edge of the timing signals.

Q.3. Define the following:

[UP Tech 2005-2006, 2006-2007]

(i) Microoperation

(ii) Microinstruction

(iii) Micro program

(iv) Microcode

Ans. Microoperation: A Microoperation is an elementary operation performed on the information stored in one or more registers. The result of the operation may replace the previous binary information of a register or may be transferred to another register. Some examples off microperations are clear, load, shift.

Microinstruction: an instruction stored in the control memory is called a microinstruction. It specifies one or more Microoperations for the system.

Micro program: A sequence of microinstructions is known as microprogram.

Microcode: it I s similar to microprogram. Once the configuration of a computer and its microprogrammed control unit is established. then microcode for the control memory.

Q.4. Explain the different cycles of an instruction execution.

[UP Tech 2006-2007]

Ans. A program is a sequence of instructions. In a computer a program is executed by going through many steps for each instruction. This is called instruction cycle. Each instruction cycle is again subdivided into a sequence of phases. There are four phases of an instruction cycle which are as follow:

1. Fetch an instruction from memory.
2. Decode the instruction.
3. Read the effective address from memory if the instruction has an indirect address.
4. Finally, execute the instruction.

After the completion of step 4, the control goes back to step 1 to fetch the next instruction. The process continues till the program is complete.

Step 1 and Step 2 (Fetch and Decode phase): Address of the first instruction is loaded in the Program counter (PC). Sequence counter (SC) is cleared to 0. SC is incremented by one, after each clock pulse. Hence timing sequence T1, T2, T3 .... is generated. The microoperations for the fetch and decode phases are shown below.

T0: AR←PC

T1: IR←M [AR], PC←PC+1

T2: D0,...., D7← Decode IR(12-14), AR←IR(0-11), I←IR(15)

At time T0, contents of PC are transferred to memory address register (AR).

At time T1, instruction is read from memory (location given by AR) and placed in instruction register (IR). At the same timing signal PC is also incremented. Now program counter (PC) will have the address of next instruction.

At time T3, decode phase of the instruction starts. Operation code bits (12-14) are decoded, the indirect bit(15) is placed in flip-flop

I, the address part of the instruction is transferred to AR. SC is incremented after each clock pulse to generate the sequence T0, T1, and T2.

Step 3 and step 4: At time T3, control unit will determine the type of the instruction which was just read from the memory. The instruction can be register reference, memory reference or input-output reference. Depending on the value of decoder output D7, it is decided which type of instruction is there. If D7 = 1, instruction can be register reference, or input-output reference.

If D7=0 then instruction is memory reference. The three instruction types are subdivided into four separate paths, which can be symbolized as given below.

D'7IT3: AR←M[AR]
D'7I'T3: Nothing
D'7I'T3: register reference is executed
D'7IT3: input-output instruction is executed.

The complete cycle of instruction execution is shown in the flow chart given below.

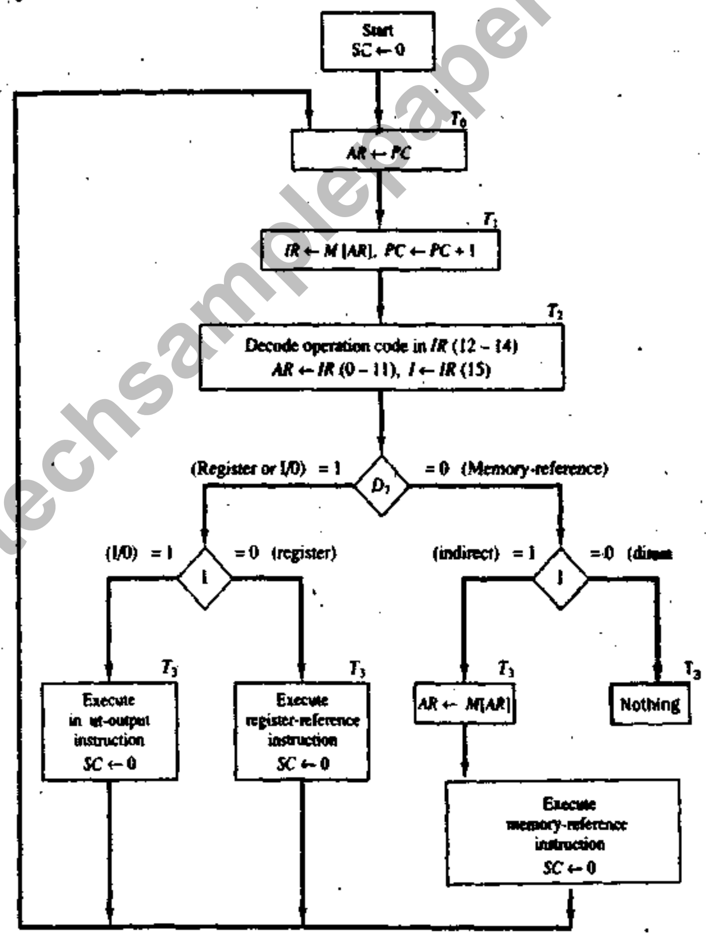

Fig. *Flowchart for instruction cycle (initial configuration).*

Q.5. Write short notes on:
(i) Multiple bus organization
(ii) Micro programmed control unit **[UP Tech 2008-2009]**

Ans. Multiple bus organization: In some programs, its resulting control sequences becomes so long because only one data item can be transferred over the bus in a clock cycle. Number of steps can be reduced by providing multiple internal paths such that many transfers can take place in parallel. Diagram given below shows a three bus structure used to connect the registers and the ALU of a processor.

In register file all the general purpose registers are present. There are three ports in register file. There are two outputs, such that at the same time contents of two registers can be accessed and their contents can be placed in bus A & bus B. the third port allows the data on bus C to be loaded into a third register during the same clock cycle. Buses A and B transfers the operands to the inputs of ALU where an arithmetic or logical operation is performed. From ALU the result is transferred to the destination through Bus C.

By providing more paths for data transfer a significant reduction in the number of clock cycles needed to execute an instruction is achieved.

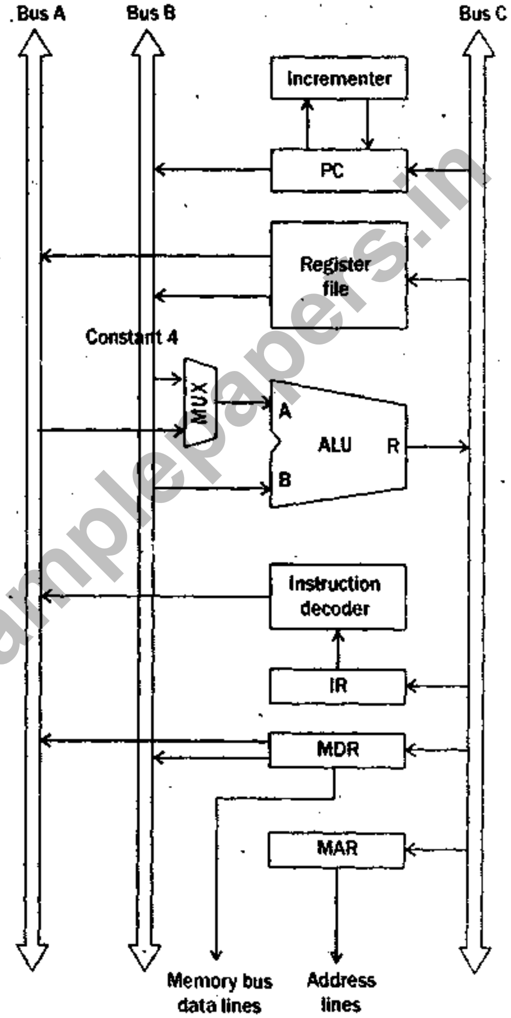

Fig. *Three-bus organization of the datapath.*

Micro programmed control unit: in a computer the function of a control unit is to initiate sequences of microoperations. There is finite number of microoperations available in any given system. Two type of design of control units are possible. When control signals are generated by hardware using logic design, the control unit is said to be hardwired. When control unit is designed with the help of microprogramming it is called *Micro programmed control unit*. The control unit initiates a series of sequential steps of microoperations. A control unit whose binary control variables are stored in memory is called a Micro programmed control unit. Each word of control memory contains a microinstruction. A sequence of microinstructions makes a microprogram.

A computer having Micro programmed control unit have two separate memories: a main memory and a control memory. A memory which is a part of control unit is called control memory. User programs are stored in main memory. Content of main memory changes when data is manipulated whereas contents of control memory are fixed as it contains micro programs which cannot be altered by the user. Microprogrammed control unit is shown in the block diagram given below.

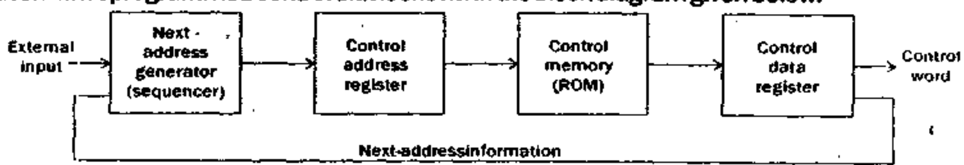

Fig. *Microprogrammed control organisation.*

It has four main parts. Sequencer, control address register, control memory, and control data register. *Control memory* is ROM which contains control information which cannot be changed. The address of the microinstruction is specified by the *control address register*. *Control data register* holds the microinstruction read from memory. It hold the present microinstruction while the next address is calculated and read from memory. It is also known as pipeline register. The *next address generator* is also known as *microprogram sequencer* because it determines the address sequence which is read from the control memory. Main function of the microprogram sequencer is to increment the control address register by one, loading an address from control memory in to the control address register.

Q.6. Explain the hardwired control unit organization explaining each component clearly. **[UP Tech 2005-2006]**

OR

What do you understand by hard wired control unit? Describe design of hard wired control unit with suitable diagram. **[UP Tech 2008-2009]**

Ans. When control organization is implemented with the help digital logic like gates, flip-flop, decoders then it is called hard wired control unit organization. In this organization if there is any change in the design then wiring between various components is also to be modified. The block diagram of Hardwired control unit organization is shown below.

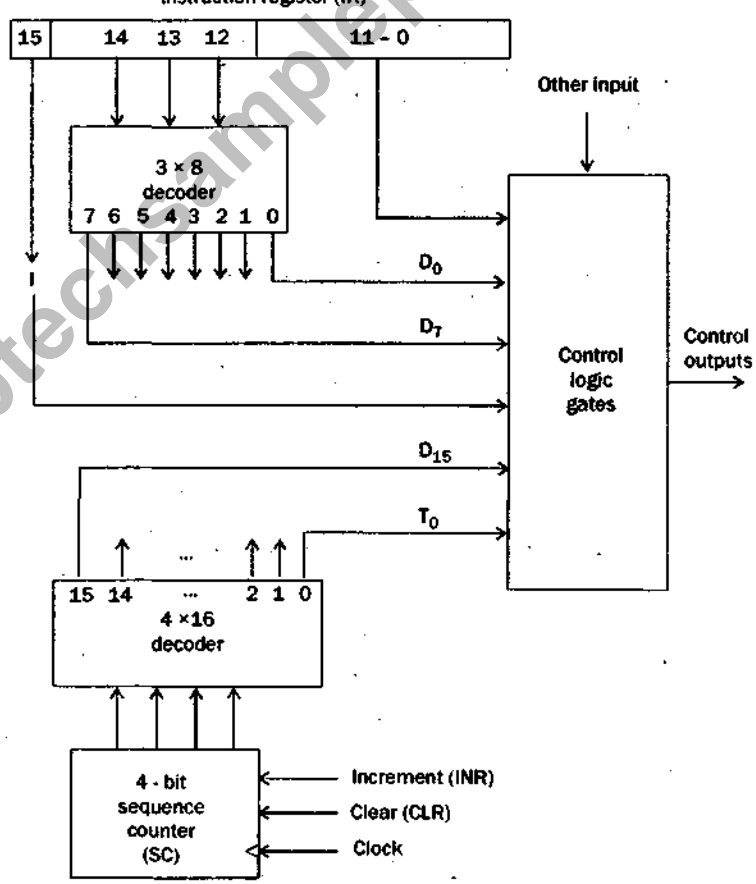

Fig. ***Control unit of basic computer.***

It consists of two decoders (3*8 decoder and 4*16 decoder), a sequence counter and control logic gates. An instruction register (IR) is also used. An instruction read from the memory is placed in IR. An instruction is divided in three parts: I bit, operation code, bits 0-11. 3* 8 decoder has three inputs and 8 outputs. Its three inputs come from instruction register. The operation code is present in bits 12-14, which is decoded by 3*8 decoder. Decoder decodes the Opcode (12-14) and result is applied to control logic gates. Another decoder which is used is 4*16 decoder. It has 4 inputs and 16 outputs. Its inputs come from sequence counter. In turn 4 *16 decoder decodes it and produces 16 timing signals T0-T15 which are applied to the control logic gates. A 4-bit sequence counter is used. Sequencer can be incremented and it cab be cleared. It produces 4 bit output. The output of sequence counter is applied to 4*16 decoder. In instruction register the operation code is present in bits 12-14, which is decoded by 3*8 decoder. Bits 0-11 are applied to control logic gates. Bit 15 is applied to flip-flop I.

Q.7. Write short notes on Hardwired and Microprogrammed control unit. [UP Tech 2004-2005, 2005-2006]

Ans. Hardwired control unit: same as above question

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A computer having Micro programmed control unit have two separate memories: a main memory and a control memory. A memory which is a part of control unit is called control memory. User programs are stored in main memory. Content of main memory changes when data is manipulated whereas contents of control memory are fixed as it contains micro programs which cannot be altered by the user. Microprogrammed control unit is shown in the block diagram given below.

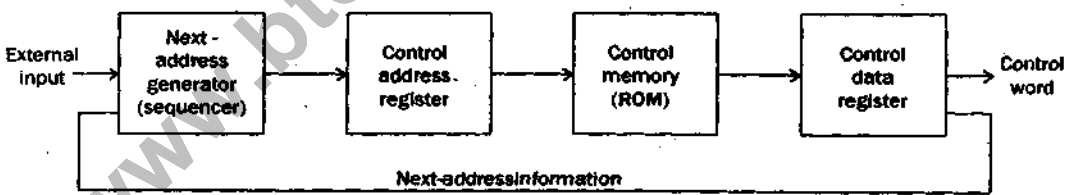

Fig. *Micropgorammedcontrol organisation.*

It has four main parts. Sequencer, control address register, control memory, and control data register. *Control memory* is ROM which contains control information which cannot be changed. The address of the microinstruction is specified by the *control address register*. *Control data register* holds the microinstruction read from memory. It hold the present microinstruction while the next address is calculated and read from memory. It is also known as pipeline register. The *next address generator* is also known as *microprogram sequencer* because it determines the address sequence which is read from the control memory. Main function of the microprogram sequencer is to increment the control address register by one, loading an address from control memory in to the control address register.

Q.8. Write the differences between Hardwired control unit and Microprogrammed control unit. **[UP Tech 2005-2006]**

Ans. There are many differences between hardwired control unit and microprogrammed control unit which are as follows:

1. In hardwired control unit, control unit is implemented with the help of gates, flip-flops and other digital circuits whereas in microprogrammed control unit controlling is done by using micro programs.
2. In microprogrammed control unit, control memory is programmed to initiate the sequence of micro operations whereas no such programming is involved in hardwired.
3. In hard wired if there is any change then in the design then the wiring (connection) between components are to be changed where as in microprogrammed control modifications are done only in the microprogram present in control memory.
4. Microprogrammed control unit is more flexible as compared to hardwired because changes like change in architecture or in instruction set can be done easily by altering the microprograms.
5. Hardwired is faster than microprogrammed control unit because generation of control signals from hardware is faster as compare to programs.

Q.9. Explain the working of micro-program sequencer with block diagram. **[UP Tech 2005-2006]**

Ans. The logic design which selects the address of next microinstruction in Microprogrammed control unit is called micro-program sequencer. It is also known as *next address generator* because it determines the address sequence which is read from the control memory. Main function of the microprogram sequencer is to increment the control address register by one, loading an address from control memory in to the control address register.

The capabilities of a sequencer required in a control memory are:

1. Incrementing of the control address register.
2. Unconditional branch or conditional branch, depending on status bit conditions.
3. A mapping process from the bits of the instruction to an address for control memory.
4. A facility for subroutine call and return.

The diagram below shows the control memory and the hardware which is requires to select the next microinstruction address.

The main components of control unit are control memory and the circuits that select the next address. The address selection part is micro program sequencer. Micro program sequencer provides an address to control memory from where microinstruction can be read and executed.

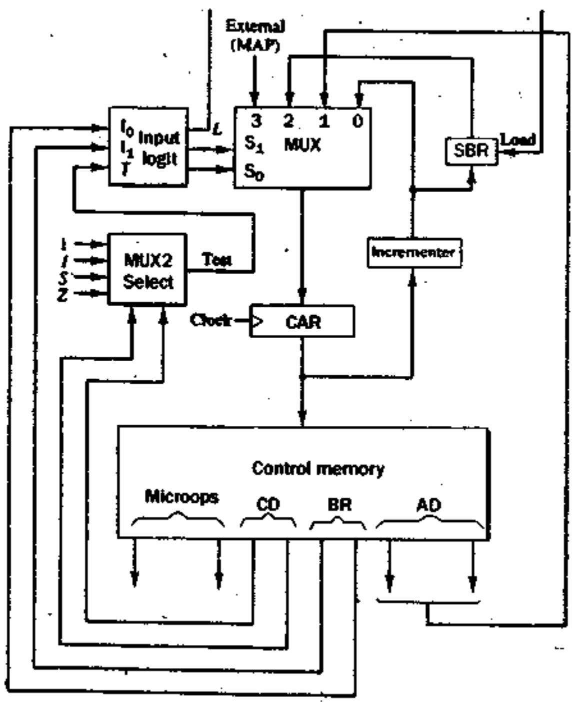

Fig. *Microprogram sequencer fora control memory.*

Working of Sequencer: In the diagram control memory is also included to show the interconnection between sequencer and memory attached to it. Two 4*1 multiplexers (MUX 1 & MUX 2) are used in the system. MUX 1 selects an address from one of the four sources and routes it to CAR (control address register). MUX 2 tests the value of selected status bit and the result of the test is applied to input logic circuit. Output of the CAR is an address to control memory. Then content of CAR is incremented and applies to MUX 1 as its input and also to the subroutine register (SBR). The other three inputs to MUX 1 come from three places:

1. Address field of present microinstruction.
2. Output of SBR.
3. External source that maps the instruction.

In the diagram only one SBR is a shown, otherwise there are normally many SBR's so that many subroutines are active at the same time. The condition field of the microinstruction selects one of the status bits in the MUX 2. It the selected bit = 1, then T (test) variable is equal to 1; otherwise it is equal to 0.there are three inputs to input logic. One is T (test) and other two are from BR (branch) coming from control memory. The input logic selects the operation (increment, call and return from subroutine, etc) which is to be performed.

Q.10. What are the characteristics of horizontal and vertical microinstructions?

Ans. Microinstructions are mainly divided into two types which are horizontal microinstruction and vertical microinstructions.

The characteristics of horizontal microinstructions are

- They have large formats.
- They have the ability to express a high degree of parallelism.
- There is less encoding of the control information.

The characteristics of vertical microinstructions are

- Such instructions have short formats.
- They have limited ability to express parallel microoperations.
- Considerable amount of encoding of control information is required.

Such instructions are very much similar to RISC instructions.