MODULE 4 – UNIVERSITY QUESTIONS

1. Explain the different methods of control organization.

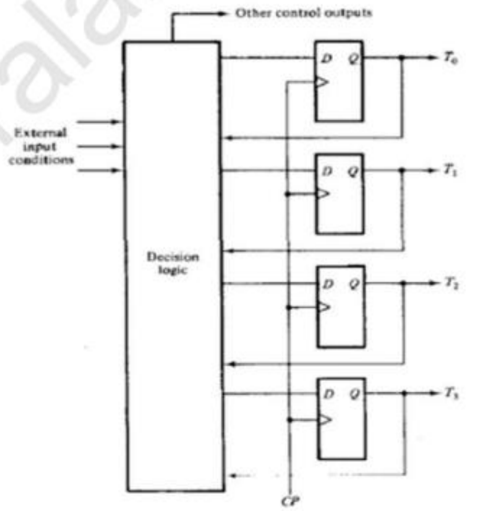
OR

What are different types of control organization?

OR

Explain the control organization in detail.

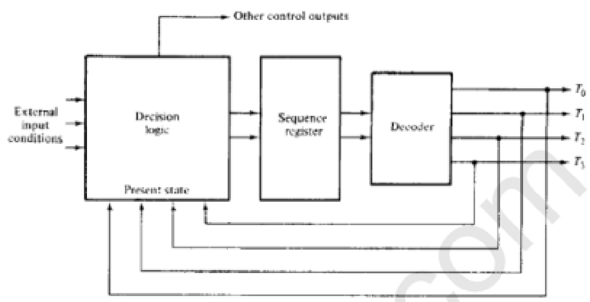
- **One flip-flop per state methods**



This method uses one flip-flop per state in the control sequential circuit. Only one flip-flop is set at any particular time: all others are cleared. A single bit is made to propagate from one flipflop to the other under the control of decision logic. In such an array, each flip-flop represents a state and is activated only when the control bit is transferred to it.

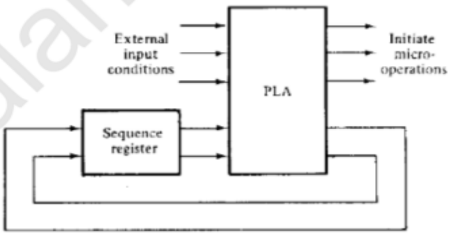
- **The advantage** of this method is the simplicity with which it can be designed.
- **The disadvantage** is that this method would increase system cost since more flip-flops are used.

- **Sequence register and decoder method**



This method uses a register to sequence the control states. The register is decoded to provide one output for each state. For n flip-flops in the sequence register, the circuit will have 2" states and the decoder will have 2" outputs.

- **PLA control**



The external sequence register establishes the present state of the control circuit. The PLA outputs determine which micro-operations should be initiated depending on the external input conditions and the present state of the sequence register. At the same time other PLA outputs determine the next state of the sequence register. The sequence register is external to the PLA if the unit implements only combinational circuits

- **Micro-program control**

Control signals are generated by a program are similar to machine language programs. The control signals associated with operations are stored in special memory units inaccessible by the programmer as Control Words (CW). A sequence of CWs corresponding to the control sequence of a machine instruction constitutes the micro routine for that instruction, and the individual control words in this micro routine are referred to as microinstructions.

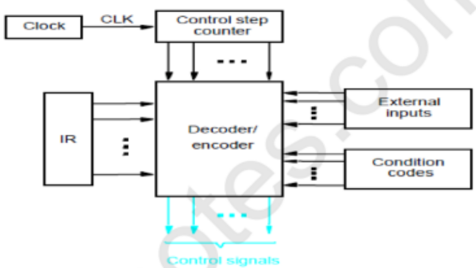
2. What are the disadvantages of sequential control logic?

- Large number of states
- Excessive number of flip-flops and gates
- Design methods uses state and excitation tables but in practice they are cumbersome

3.

Explain hardwired control.

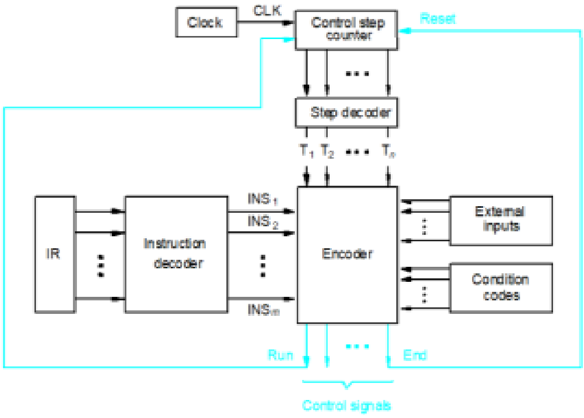
The control hardware can be viewed as a state machine that changes from one state to another in every clock cycle, depending on the contents of the instruction register, the condition codes and the external inputs.



The outputs of the state machine are the control signals. The sequence of the operation carried out by this machine is determined by the wiring of the logic elements and hence named as "hardwired". Fixed logic circuits that correspond directly to the Boolean expressions are used to generate the control signals.

4.

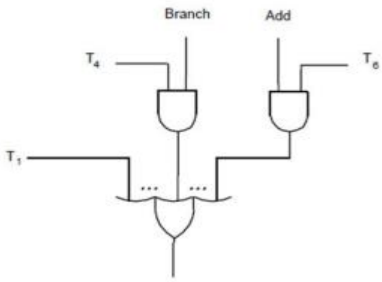
Explain the design a hardwired control for a simple control signal with an example.

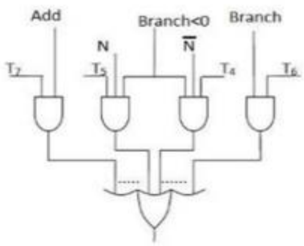


Example

Zin=T1+T6.Add+T4.BR+…..

END= T7.Add+T5.BR+(T5.N+T4.N')BRN





5.

Explain the advantages and disadvantages of hardwired control.

Advantages: High Speed

Disadvantages: requires changes in the wiring if the design has to be modified or changed- less flexible, Costly, and difficult to implement complex instructions

6.

. **Define the terms Control word, Micro routine, Micro instructions, Micro program, Control store.**

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.

Micro-instruction : 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.

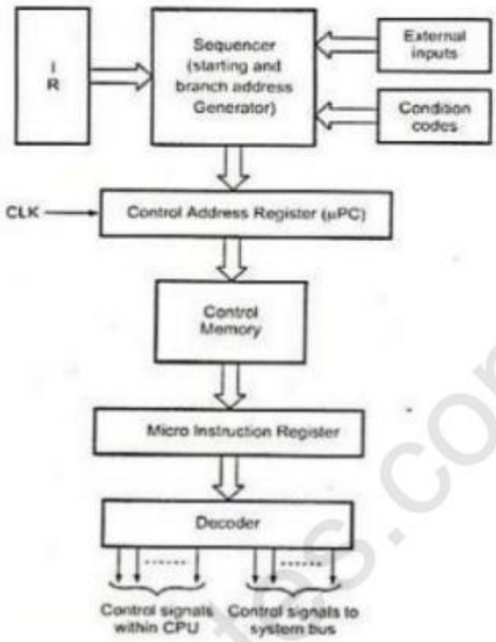
7.

Discuss the principle operation of micro programmed control unit.

Control variables that initiate micro-operations are stored in memory. The control memory is usually a ROM, since the control sequence is permanent and needs no alteration. The control variables stored in memory are read one at a time to initiate the sequence of micro-operations for the system. Each micro operation is associated with a specific set of control lines which, when activated, causes that micro operation to take place.

8.

Explain the components of microprogrammed control unit.



Control memory: In micro programmed control, the micro programs for all instructions are stored in the control memory (CM). The control signals to be activated at any time are specified by a microinstruction, which is fetched from Control memory (CM).

Control address register : The control address register holds the address of the next microinstruction to be read. When address is available in control address register, the sequencer issues READ command to the control memory.

Microinstruction register : After issue of READ command, the word from the addressed location is read into the microinstruction register. Now the content of the micro instruction register generates control signals and next address information for the sequencer.

Micro-program sequencer : A sequence of one or more micro operations designed to control specific operation, such as addition, multiplication is called a micro program. The sequencer loads a new address into the control address register based on the next address information

9.

. List the advantages and disadvantages of microprogrammed control unit

Advantages

- It simplifies the design of control unit. Thus it is both, cheaper and less error prone implement.
- Control functions are implemented in software rather than hardware.
- The design process is orderly and systematic
- More flexible, can be changed to accommodate new system specifications or to correct the design errors quickly and cheaply.
- Complex function such as floating point arithmetic can be realized efficiently.

Disadvantages

- A micro programmed control unit is somewhat slower than the hardwired control unit, because time is required to access the microinstructions from CM
- The flexibility is achieved at some extra hardware cost due to the control memory and its access circuitry.

10. Write the control sequence and micro instructions for the instruction Add (R3),R1

1. PCout, MARin, Read, Select4, Add, Zin
2. Zout, PCin, Yin, Wait for the MFC
3. MDRout, IRin
4. R3out, MARin, Read
5. R1out, Yin, Wait for MFC
6. MDRout, Select Y, Add, Zin
7. Zout, R1in, End

The microinstruction for the above control sequence can be expressed as follows.

Micro - instruction	••	PC_{in}	PC_{out}	MAR_{in}	Read	MDR_{out}	IR_{in}	Y_{in}	Select	Add	Z_{in}	Z_{out}	$R1_{out}$	$R1_{in}$	$R3_{out}$	WMFC	End	••
1		0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	
2		1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	
3		0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	
4		0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	
5		0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	
6		0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	
7		0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	

11. Compare instruction formats of horizontal and vertical microinstructions?

OR

Explain Horizontal and vertical micro instructions.

A **horizontal microinstruction** is a minimally encoded scheme. The scheme of micro-instruction by assigning one bit position to each control signal is called horizontal micro-instructions.

Example: 011101001101001110

In a horizontal microinstruction every bit in the control field attaches to a controller. Horizontal microinstructions represent several micro-operations that are executed at the same time. A horizontal approach involves a wider control store, but is capable of greater speed.

Vertical microinstruction is a tightly encoded scheme. The vertical approach requires a narrow control store, but must be decoded in order to drive the actual control lines, thus introducing a delay in driving the control lines.

F1 (4 bits)	F2 (3 bits)	F3 (3 bits)	AS3 AS2 AS1	Read	Write	Carry-in	WMFC	End
0000: No action	000: No action	000: No action	000: ADD					
0001: PCout	001: PCin	001: MARin	001: INC					
0010: MDRout	010: IRin	010: MDRin	010: SUB					
0011: Zout	011: Zin	011: TEMPin	011: DEC					
0100: R0out	100: R0in	100: Yin	100: AND					
0101: R1out	101: R1in		101: OR					
0110: R2out	110: R2in		110: XOR					
0111: R3out	111: R3in		111: NOT					
1000: IRout								
1001: TEMPout								

12.

Compare Horizontal and vertical micro instructions.

Horizontal	Vertical
Long formats.	Short formats
Ability to express a high degree of parallelism.	Limited ability to express parallel micro operations.
Little encoding of the control information.	Considerable encoding of the control information
Useful when higher operating speed is desired.	Slower operating speeds.

13. Illustrate the working of a micro program sequencer with the help of diagrams

OR

List the address-sequencing capabilities of a microprogram sequencer. With a suitable block diagram and function table, explain the organization of a typical microprogram sequencer

OR

With the help of a block diagram and function table, illustrate the functioning of a microprogram sequencer in a control unit designed for a processor that supports both arithmetic and logical operations.

OR

With the help of a diagram explain the functioning of a micro-program sequencer in a micro-programmed controlled processor?

OR

. Explain the design of a micro program sequencer in detail.

Micro program sequencer is a control unit which does the tasks of Micro-program sequencing.

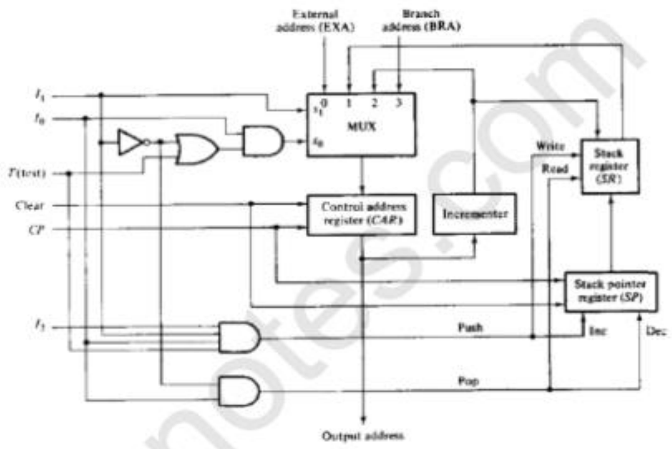
A micro-program sequencer works in a way to generate these control signals from the microprogram
by transitioning from one state to another in every clock cycle. A state is defined by the
micro-instruction that has to be run in that clock cycle.It has two main functions
1. **Control Function** The micro-operations that need to be executed to perform a certain microinstruction
are to be defined and be known. The micro-operation(s) are dependent on parameters
like selected destination, operand etc.
2. **Sequencing Function** The address of next micro-instruction to be executed is generated while
controlling test conditions etc.
Thus, to summarize, to execute an instruction, the microprogram sequencer executes a micro-instruction
in every clock cycle and determines which micro-instruction (state) to run next. It can be thought in terms
of a state diagram.

Micro-program sequencer is attached to the control memory.

It inspects certain bits in the microinstruction to determine the next address for control memory.

A typical sequencer has the following address sequencing capabilities.

1. Increments the present address of control memory
2. Branches to an address which will be specified in the bits of microinstruction
3. Branches to a given address if a specified status bit is equal to 1.
4. Transfers control to a new address as specified by an external source
5. Has a facility for subroutines calls and returns.



The block diagram of **Micro-program Sequencer** is shown in the figure. It consists of a multiplexer that selects an address from **four sources** and routes it into a Control Address Register (CAR).

1. Transfers control to a new address specified by an external source (EXA).
2. Transfers control to a new address for subroutines call (SR) and returns.
3. Increments the present address of control memory (Incrementer)
4. Branches to an address which will be specified in the bits of microinstruction (BRA).

- **Multiplexer**: Selects an address from four source s and routes it into CAR.
- The output from CAR provides the address for control memory to read a microinstruction.
- The contents of CAR are incremented and applied to the multiplexer and to the stack register file (SR).

- The register selected in the stack is determined by stack pointer (SP).
- Inputs (I_0-I_2) specify the operation for the sequencer and input.
- T is the test point for a status bit. I

Initially the address register is cleared to zero and clock pulse synchronizes the loading into registers. [In table X indicates don't care]

Function table

I_2	I_1	I_0	T	s_1	s_0	Operation	Comments
X	0	0	X	0	0	$CAR \leftarrow EXA$	Transfer external address
X	0	1	X	0	1	$CAR \leftarrow SR$	Transfer from register stack
X	1	0	X	1	0	$CAR \leftarrow CAR + 1$	Increment address
0	1	1	0	1	0	$CAR \leftarrow CAR + 1$	Increment address
0	1	1	1	1	1	$CAR \leftarrow BRA$	Transfer branch address
1	1	1	0	1	0	$CAR \leftarrow CAR + 1$	Increment address
1	1	1	1	1	1	$CAR \leftarrow BRA,\ SR \leftarrow CAR + 1$	Branch to subroutine

14.

. Compare and contrast hardwired and micro programmed control units.

Hardwired control	**Microprogrammed control**
Hardwired control unit generates the control signals needed for the processor using logic circuits	Micrprogrammed control unit generates the control signals with the help of micro instructions stored in control memory
Faster	Slower
Difficult to modify as the control signals that need to be generated are hard wired	Easy to modify as the modification need to be done only at the instruction level
More costlier as everything has to be realized in terms of logic gates	Less costlier than hardwired control as only micro instructions are used for generating control signals
It cannot handle complex instructions as the circuit design for it becomes complex	It can handle complex instructions
Only limited number of instructions are used due to the hardware implementation	Control signals for many instructions can be generated
Used in computer that makes use of Reduced Instruction Set Computers(RISC)	Used in computer that makes use of Complex Instruction Set Computers(CISC)

15.Explain micro programmed CPU organization with the help of a diagram.

OR

Design a microprogrammed CPU organization for a computer system capable of executing arithmetic, logic, and data transfer instructions.

OR

Explain the organization of micro-programmed computer with a block diagram?

Digital computer consists of: Central Processing Unit(CPU), Memory unit and Input-output devices. CPU can be divides into 2 distinct and interactive sections namely

- *Processing section*: useful device for constructing the processor section of a CPU and
- *Control section*: controlling the entire units of computer

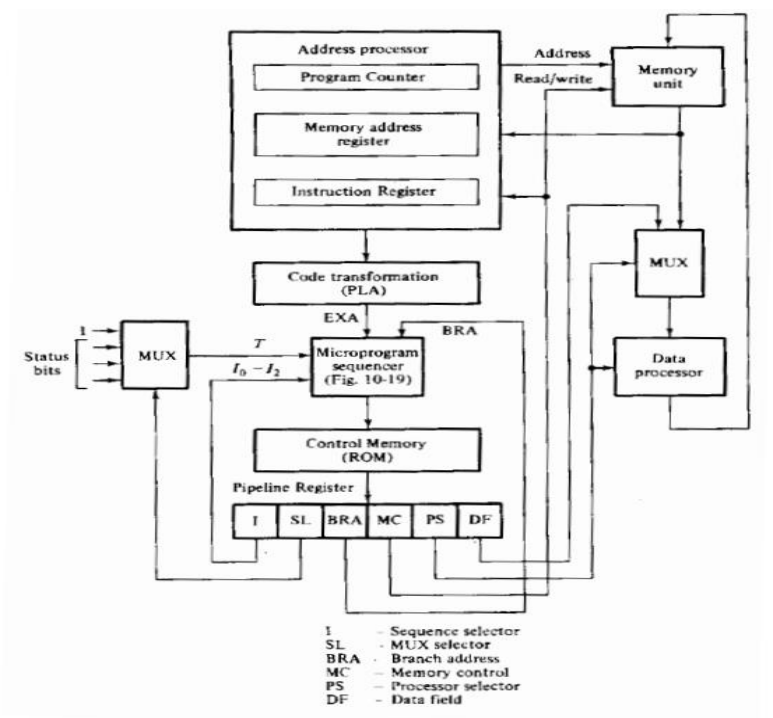
Mmicro-program sequencer: constructing a micro-program control of CPU

Micro-programmed computer

A computer CPU uses the micro-program sequencer. Micro-programmed computer consists of

1. Memory unit: Stores instructions and data supplied by the user through an input device
2. Two processor unit:
   Data processor: Manipulates data
   Address processor: Manipulates the address information received from memory
3. A Micro-program sequencer
4. A control memory
5. Other digital functions
   - An instruction extracted from memory unit during fetch cycle goes into instruction register and is decoded.
   - Corresponding to each opcode (Add, sub), there will be a micro routine in the control memory.

   - Code transformation constitutes a mapping function that is needed to convert the op code bits of an instruction into a starting address for the control memory.
   - It is implemented with ROM or PLA.
   - Mapping concept provides flexibility for adding instructions or micro-operations for control memory as need arises.
   - The address generated in code transformation mapping function is applied to the external address (EXA) input of the sequencer.



Micro-programmed Computer Organization

Micro-program control unit consists of

1. *The sequencer*: Generates next address
2. *A control memory:* Reads the next microinstruction while present microinstruction are being executed in the other units of the CPU and for storing microinstructions

3. *A multiplexer:* Selects one of the many status bits and applies to the T(test) input of the sequencer. One of the input of the multiplexer is always I to provide an unconditional branch operation

A **pipeline register**: Speed up the control operation, allows next address to be generated and the output of control memory to change while the current control word in pipeline register initiates the micro-operations given by present microinstruction. It's not always necessary because the output of control memory can go directly to the control inputs of the various units in the CPU

Microinstruction format contains six fields:

First 3 fields (I,SL, BRA) provide information to the sequencer to determine the next address for control memory.

I field (3 bits): Supplies input information for the sequencer

SL field: Selects a status bit for the multiplexer

BRA field: Address field of microinstruction and supplies a branch address (BRA) to the sequencer.

The next 3 fields (MC, PS, DF) are for controlling micro-operations in the processor and the memory units

Memory control (MC) field: Controls the address processor and the read and write operations in the memory unit.

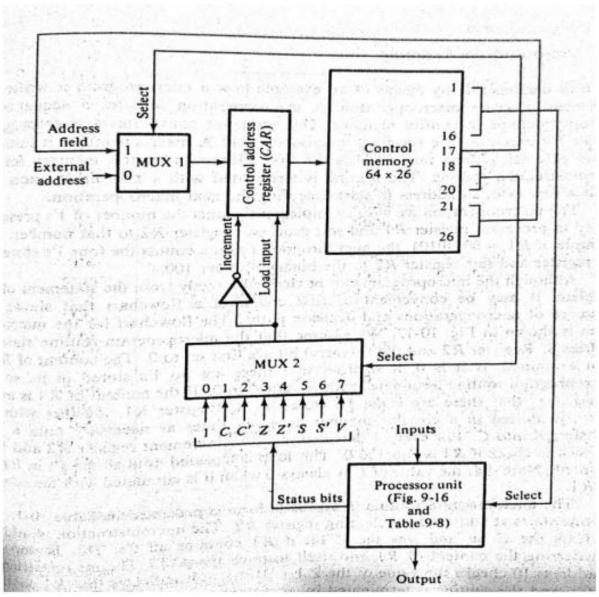
The processor select(PS) field: Controls the operations in the data processor unit.

The data field(DF): Used to introduce constants into the processor

Output from data field may be used to set up control registers and introduce data in processor registers.

16.

Outline with the help of a block diagram, how a micro program control unit can be used for controlling the processor unit.



17. Illustrate the steps for designing a micro programmed control circuit for the addition and subtraction of binary numbers in sign magnitude form. Specify the block diagram of control circuitry and the binary micro program for control memory.

OR

With the help of a flowchart for sign-magnitude addition/subtraction, explain the steps involved in developing a hardwired control unit?

(Algorithm/ flowchart specification - 3 marks Hardware configuration - 4 marks Symbolic micro program - 3 marks Binary micro program - 4 marks)

The two signed binary numbers to be added or subtracted contain n bits. The magnitudes of the numbers contain k = n - 1 bits and are stored in registers A and B. The sign bits are stored in flip-flops A_s and B_s.

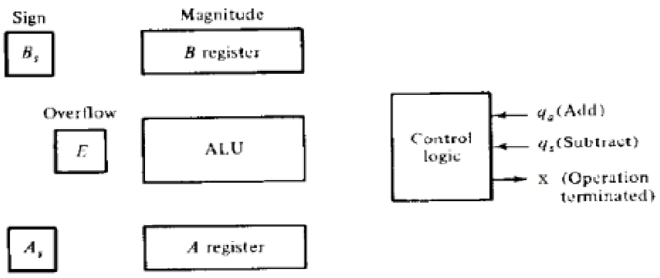


Figure 10-6 Register configuration for the adder-subtractor

Figure shows the registers and associated equipment. The ALU performs the arithmetic operations and the 1-bit register E serves as the overflow flip-flop. The output carry from the ALL) is transferred to E.

It is assumed that the two numbers and their signs have been transferred to their respective registers and that the result of the operation is to be available in registers A and A_s. Two input signals in the control specify the add (q_a) and subtract (q_s) operations. Output variable x indicates the end of the operation.

The control logic communicates with the outside environment through the input and output variables. Control recognizes input signal q_a or q_s and provides the required operation. Upon completion of the operation, control informs the external environment with output x that the sum or difference is in registers A and A, and that the overflow bit is in E.

Designate the magnitude of the two numbers by A and B. When the numbers are added or subtracted algebraically, there are eight different conditions to consider, depending on the sign of the numbers and the operation performed. The eight conditions may be expressed in a compact form as follows:

$$(\pm A) \pm (\pm B)$$

If the arithmetic operation specified is subtraction, we change the sign of B and add. This is evident from the relations:

$$(\pm A) - (+B) = (\pm A) + (-B)$$
$$(\pm A) - (-B) = (\pm A) + (+B)$$

This reduces the number of possible conditions to four, namely:

$$(\pm A) + (\pm B)$$

The four possible combination are

When the signs of A and B are the same: $(+A) + (+B) = +(A + B)$

$(-A) + (-B) = -(A + B)$

When the signs of A and B are not the same

$(+A) + (-B) = +(A - B)$ [if(A>B)]

$-(B - A)$ [if(B>A)]

$(-A) + (+B) = -(A - B)$ [if(A>B)]

$+(B - A)$ [if(B>A)]

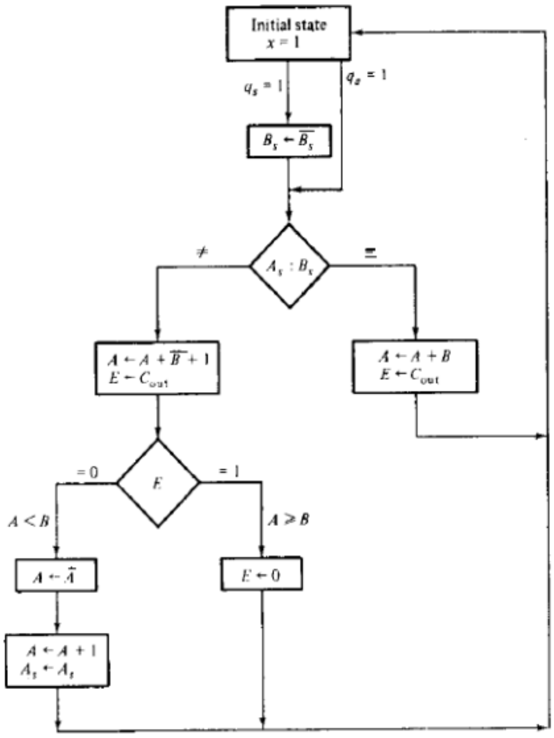


Figure 10-7 Flowchart for sign-magnitude addition and subtraction

The flowchart shows how we can implement sign-magnitude addition and subtraction with the equipment as shown in previous diagram.

Figure (a) shows the data-processor with the required control variables. This ALU has four selection variables, as shown in the diagram. The variable L loads the output of the ALU into register A and also the output carry into E. Variables y, z. and w complement B, and A, and clear E, respectively.

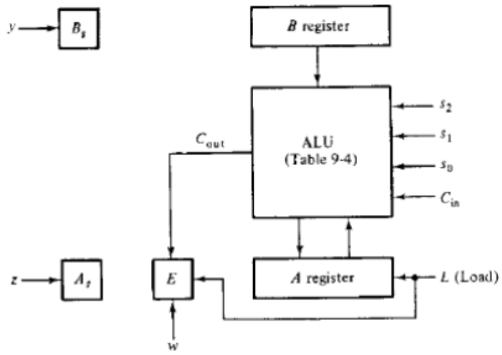


Figure a. Data Processor Register and ALU

This variable gives the result of the comparison between the two sign bits. The exclusive-OR operation is equal to 1 if the two signs are not the same, and it is equal to 0 if the signs are both positive or both negative. The control provides an output x for the external circuit. It also selects the operations in the ALU through the four selection variables S_2, S_1, S_0, and C_{in}. The other four outputs go to registers in the data-processor as specified in the diagram.

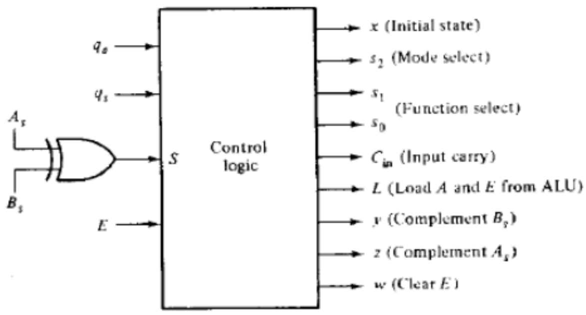


Figure b. Control Block Diagram

	Control outputs								
	x	s_2	s_1	s_0	C_{in}	L	y	z	w
T_0: Initial state $x = 1$	1	0	0	0	0	0	0	0	0
$T_1: B_s \leftarrow \overline{B}_s$	0	0	0	0	0	0	1	0	0
T_2: nothing	0	0	0	0	0	0	0	0	0
$T_3: A \leftarrow A + B,\ E \leftarrow C_{out}$	0	0	0	1	0	1	0	0	0
$T_4: A \leftarrow A + \overline{B} + 1,\ E \leftarrow C_{out}$	0	0	1	0	1	1	0	0	0
$T_5: E \leftarrow 0$	0	0	0	0	0	0	0	0	1
$T_6: A \leftarrow \overline{A}$	0	1	1	1	0	1	0	0	0
$T_7: A \leftarrow A + 1,\ A_s \leftarrow \overline{A}_s$	0	0	0	0	1	1	0	1	0

18. Draw and discuss about PLA control logic?

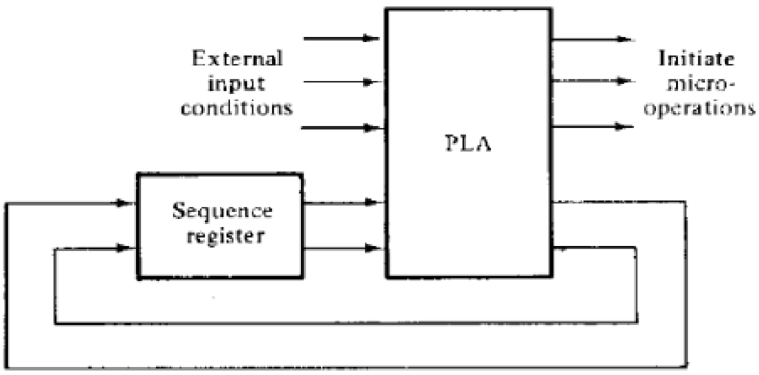
OR

Explain PLA based control organization with the help of a diagram

OR

Give the key characteristics of PLA-based control organization and its advantages.

The external sequence register establishes the present state of the control circuit. The PLA outputs determine which micro-operations should be initiated depending on the external input conditions and the present state of the sequence register. At the same time other PLA outputs determine the next state of the sequence register.



The sequence register is external to the PLA if the unit implements only combinational circuits. Some PLAs include not only gates but also flip-flops within the unit. This implements a sequential circuit by specifying the links that must be connected to the flip-flops in manner that the gate links are specified

By using the PLA for combinational circuit it is possible to reduce the number of IC's and the number of interconnection wires.

19. With a diagram, explain how control signals are generated using hardwired control?

OR

Explain the procedure for designing a hardwired control, using an appropriate example.

- Control hardware design can be assumed as a sequential digital system design.
  - As per the contents of IR, the external inputs and states are selected.
  - The outputs are the control signals
- Hardwire design of control system assumes the design the data flow as per the wiring/ connection of the components
- The design of hardwired control is carried out in 5 consecutive steps
  1. The problem is stated
  2. An initial equipment configuration is assumed
  3. An algorithm is formulated
  4. The data processor part is specified
  5. The control logic is designed

For each instruction, the control unit causes the CPU to execute a sequence of steps correctly. In reality, there must be control signals to assert lines on various digital components to make things happen. For example, when we perform an Add instruction in assembly language, we assume the addition takes place because the control signals for the ALU are set to "add" and the result is put into the AC. The ALU has various control lines that determine which operation to perform. The question we need to answer is, "How do these control lines actually become asserted?" We can take one of two approaches to ensure control lines are set properly. The first approach is to physically connect all of the control lines to the actual machine instructions. The instructions are divided up into fields, and different bits in the instruction are combined through various digital logic components to drive the control lines. This is called hardwired control, and is illustrated in figure (1). The control unit is implemented using hardware (for example: NAND gates, flip-flops, and counters).We need a special digital circuit that uses , as inputs, the bits from the Opcode field in our instructions, bits from the flag (or status) register, signals from the bus, and signals from the clock. It should produce, as outputs, the control signals to drive the various components in the computer. The advantage of hardwired control is that is very fast. The disadvantage is that the instruction set and the control logic are directly tied together by special circuits that are complex and difficult to design or modify.

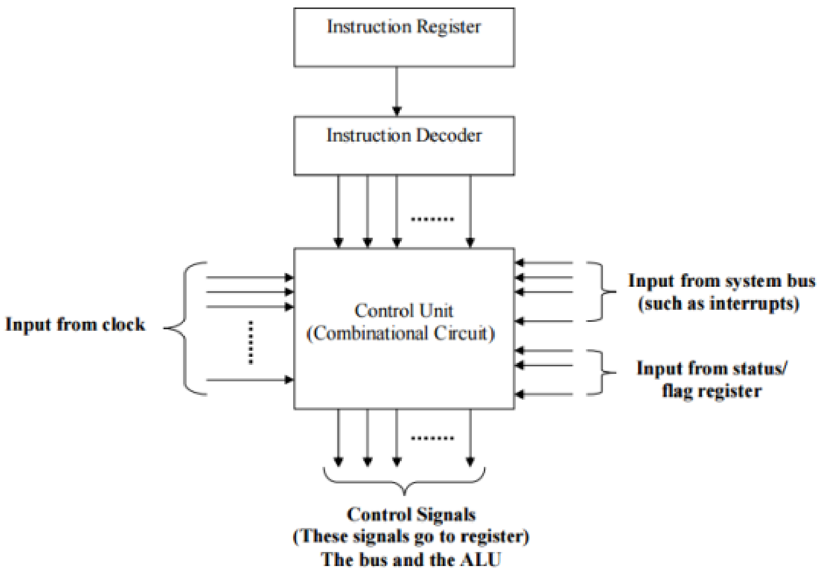
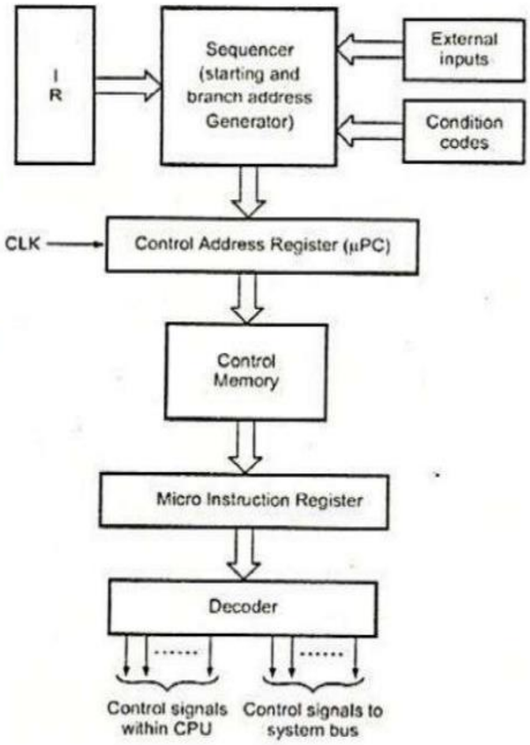


Figure (1) Hardwired Control Organization

If someone designs a hardwired computer and later decides to extend the instruction set, the physical components in the computer must be changed. This is prohibitively expensive, because not only must new chips be fabricated but also the old ones must be located and replaced.

20. What are the different elements involved in micro-program control unit explain with a neat diagram?

- ***Control memory:*** micro programs for all instructions are stored in the control memory (CM). The control signals to be activated are specified by a microinstruction, fetched from Control memory (CM).
- ***Control address register:*** Holds the address of the next microinstruction to be read. When address is available in control address register, the sequencer issues READ command to the control memory.
- ***Microinstruction register:*** After issue of READ command, the word from the addressed location is read into the microinstruction register. The content of the micro instruction register generates control signals and next address information for the sequencer.
- ***Micro-program sequencer :*** A sequence of one or more micro operations designed to control specific operation, such as addition, multiplication is called a micro program. The sequencer loads a new address into the control address register based on the next address information



(Explain other elements in the diagram also)

21. Discuss about sequence register and decoder method of control organization?

This method uses a register to sequence the control states. The register is decoded to provide one output for each state. For n flip-flops in the sequence register, the circuit will have 2" states and the decoder will have 2" outputs.

For example, a 4-bit register can be in any one of 16 states. A 4 x 16 decoder will have 16 outputs, one for each state of the register. Both the sequence register and decoder are MS1 devices.

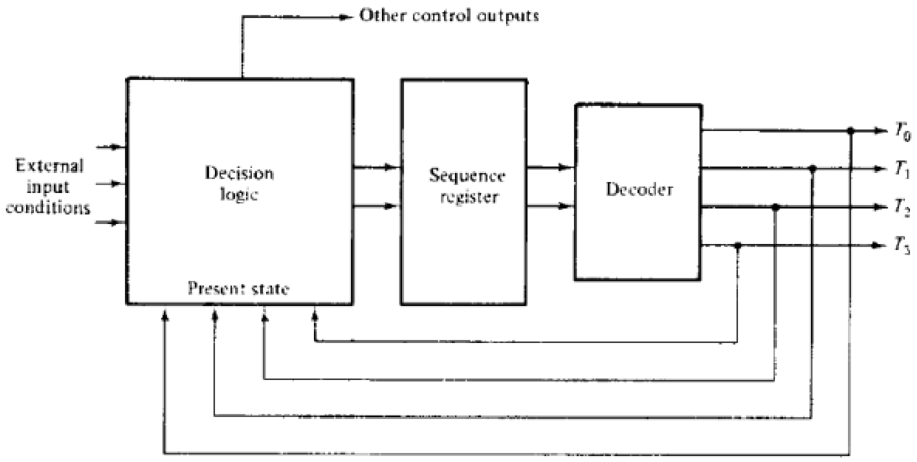


Figure shows the configuration of a four-state sequential control logic. The sequence register has two flip-flops and the decoder establishes separate outputs for each state in the register. The transition to the next state in the sequence register is a function of the present state and the external input conditions.

If the control circuit does not need external inputs the sequence register reduces to a counter that continuously sequence through the four states so called **counter decoder method**

22. Write a note on micro-program control?

The purpose of control unit is to initiate a series of sequential steps of micro-operations. At any given time certain operations are to be initiated while all others remain idle. The control variable at any given time can be represented by a string of 1's and 0's called ***control word***. The control words can be programmed to initiate the various components in the system in an organized manner.

A control unit whose control variables are stored in a memory called a ***micro-programmed control*** unit. Each control word of memory is called ***Microinstruction*** and Sequence of microinstructions is called ***Micro-program***.

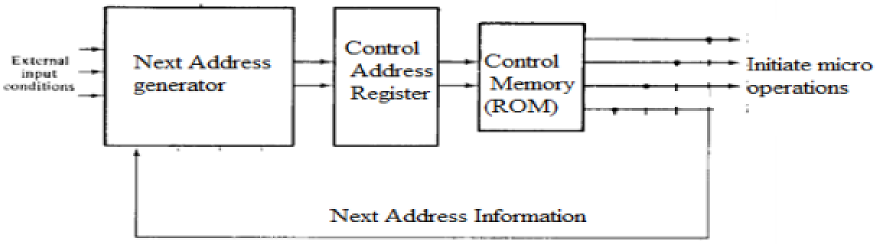
Control memory is usually ROM since an alteration of micro-program is seldom needed. The use of micro-program involves placing all control variables in words of the ROM for use by the control unit through successive read operations. The content of the word in the ROM at a given address specifies the micro-operations for the system.

Dynamic micro-programming permits a micro-program to be loaded initially from the computer console or from an auxiliary memory such as magnetic disk. Writable control memory

(WCM) can be used for writing but used mostly for reading. A ROM, PLA or WCM when used in a control unit is referred as a control memory

Control memory address register specifies the control word read from control memory. The ROM operates as a combinational circuit with address value as the input and the corresponding word as the output. The content of the specified word remains on the output wires as long as the address value remains in the address register.

If the address registers changes while the ROM word is still in use then the word out of the ROM should be transferred to a buffer register. If the change in address and ROM word can occur simultaneously no buffer register is needed. The word read from memory represents a microinstruction. The microinstruction specifies one or more micro-operations for the components of the system.

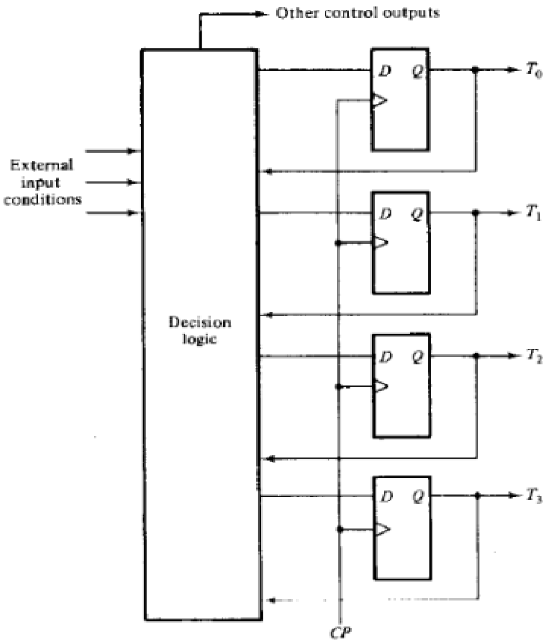


Once these operations are executed, the control unit must determine its next address. The location of the next microinstruction may be next one in the sequence or it may locate somewhere else in the control memory. Some bits of the microinstruction to control the generation of the address for the next microinstruction.

The next address may be function of external input conditions. The next address is computed in the next address generator circuit and then transferred into the control address register to read the next microinstruction.

23. Explain with an example one flip-flop per state method of control organization?

This method uses one flip-flop per state in the control sequential circuit. Only one flip-flop is set at any particular time: all others are cleared. A single bit is made to propagate from one flip-flop to the other under the control of decision logic. In such an array, each flip-flop represents a state and is activated only when the control bit is transferred to it.



In this method, maximum numbers of flip-flops were used. Example: A sequential circuit with 12 states requires a minimum of four flip-flops because $2^3 < 12 < 2^4$. Control circuit uses 12 flip-flops, one for each state

The ***advantage*** of this method is the simplicity with which it can be designed. This type of controller can be designed by inspection from the state diagram that describes the control sequence. This also offers other advantages like savings in design effort, an increase in operational simplicity, and a potential decrease in the combinational circuits required to implement the complete sequential circuit. The ***disadvantage*** is that this method would increase system cost since more flip-flops are used.

Figure shows the configuration of a four-state sequential control logic that uses four D-type flip-flops: one flip-flop per state T_i, i = 0, 1, 2, 3.

At any given time interval between 2 clock pulses, only one flip-flop is equal to 1; all others are 0. The transition from the present state to next state is a function of the present T_i that is a 1 and certain input conditions.

The next state is manifested when the previous flip-flop is cleared and a new one is set. Each of the flip-flops is connected to the data processing section of the digital system to initiate certain micro-operations. The control outputs are a function of the T's and external inputs. These outputs may also initiate micro-operations

If control circuit does not need external inputs for its sequencing, the circuit reduces to straight **shift register** with a single bit shifted from one position to the next. If control sequence must repeated over and over again the control reduces to **ring counter.**

Ring counter is a shift register with the output of last flip-flop connected to the input of the first flip-flop. In a ring counter single bit continuously shifts from one position to the next in a circular manner.

For this reason, this method is also called **ring counter controller**

24. Enumerate the differences between hardwired control and microprogram control.

OR

Give the advantages and disadvantages of hardwired control over microprogrammed control.

Hardwired control unit generates the control signals needed for the processor using logic circuits	Microprogrammed control unit generates the control signals with the help of micro instructions stored in control memory
Hardwired control unit is faster when compared to microprogrammed control unit as the required control signals are generated with the help of hardwares	This is slower than the other as micro instructions are used for generating signals here
Difficult to modify as the control signals that need to be generated are hard wired	Easy to modify as the modification need to be done only at the instruction level
More costlier as everything has to be realized in terms of logic gates	Less costlier than hardwired control as only micro instructions are used for generating control signals
It cannot handle complex instructions as the circuit design for it becomes complex	It can handle complex instructions
Only limited number of instructions are used due to the hardware implementation	Control signals for many instructions can be generated
Used in computer that makes use of Reduced Instruction Set Computers(RISC)	Used in computer that makes use of Complex Instruction Set Computers(CISC)

25. Differentiate between horizontal and vertical microinstructions

Horizontal	Vertical
Long formats.	Short formats
Ability to express a high degree of parallelism.	Limited ability to express parallel micro operations.
Little encoding of the control information.	Considerable encoding of the control information
Useful when higher operating speed is desired.	Slower operating speeds.
The minimally encoded scheme in which resources can be controlled with a single instruction is called horizontal organization	Highly encoded scheme that use compact codes to specify only a small number of control functions in each micro instruction are referred to as a vertical organization

Advantages: Fast execution Disadvantages: i. Size of micro instruction is too large ii. Most signals are not needed simultaneously iii. Many signals are mutually exclusive. ie; only one function of ALU can be activated at a time.	Advantage: Fewer bits are required in the microinstruction. Disadvantage:Vertical approach results in slower operations speed.

26. What is a control word? With an example, show how a control word can be defined.

The control function specifying a microoperation is a binary variable whose active state could be either 1 or 0.

– In the variable's active state, the microoperation is executed.

– The string of control variables which control the sequence of microoperations is called a control word.

• The microoperations specified in a control word is called a microinstruction.

– Each microinstruction specifies one or more microoperations that is performed.

• The control unit coordinates stores microinstruction in its own memory (usually ROM) and performed the necessary steps to execute the sequences of microinstructions (called microprograms).

	x	s_2	s_1	s_0	C_{in}	L	y	z	w
T_0: Initial state $x = 1$	1	0	0	0	0	0	0	0	0
$T_1: B_s \leftarrow \bar{B}_s$	0	0	0	0	0	0	1	0	0
T_2: nothing	0	0	0	0	0	0	0	0	0
$T_3: A \leftarrow A + B,\ E \leftarrow C_{out}$	0	0	0	1	0	1	0	0	0
$T_4: A \leftarrow A + \bar{B} + 1,\ E \leftarrow C_{out}$	0	0	1	0	1	1	0	0	0
$T_5: E \leftarrow 0$	0	0	0	0	0	0	0	0	1
$T_6: A \leftarrow \bar{A}$	0	1	1	1	0	1	0	0	0
$T_7: A \leftarrow A + 1,\ A_s \leftarrow \bar{A}_s$	0	0	0	0	1	1	0	1	0