Pipelining

- It is a technique of decomposing a sequential process into suboperations, with each subprocess being executed in a special dedicated segment that operates concurrently with all other segments.
- It can be visualized as a collection of processing segments through which binary information flows.
- Each segment performs partial processing by the way the task is partitioned.
- The result obtained from the computation in each segment is transferred to the next segment in the pipeline.
- The final result is obtained after the data have passed through all segments.

Example- $A_i * B_i + C_i$, for $i = 1$ to 7.

→ The suboperation performed in each segment of the pipeline are as follows-

$R_1 \leftarrow A_i$, $R_2 \leftarrow B_i$ Input A_i and B_i

$R_3 \leftarrow R1 * R2$, $R4 \leftarrow C$ Multiply and Input C_i

$R5 \leftarrow R3 + R4$ Add C_i to the product

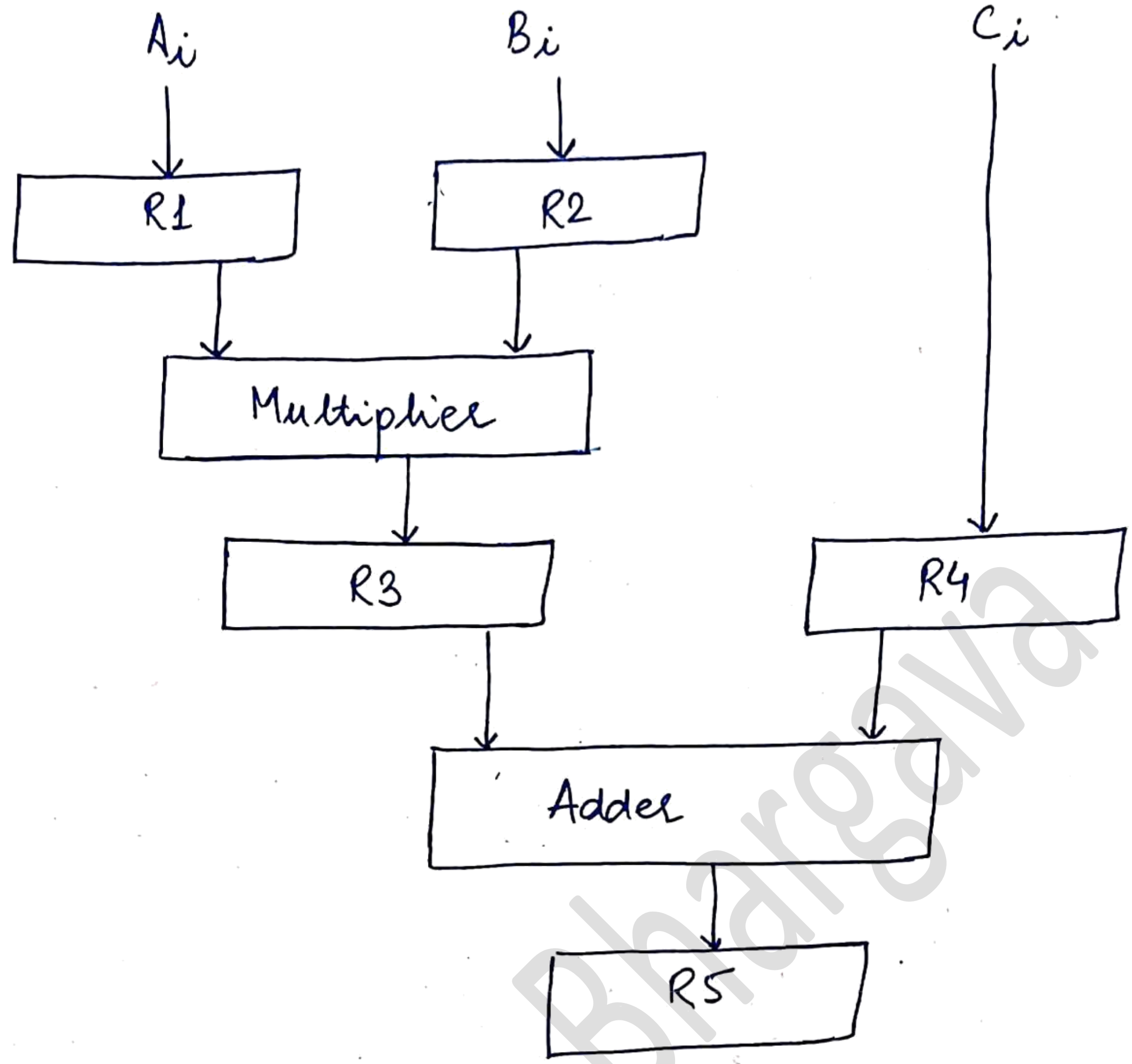
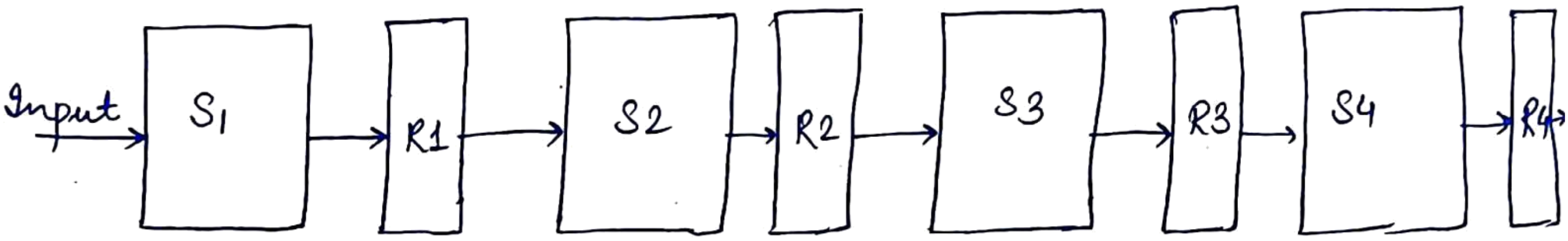


Fig :- Example of pipeline processing

Clock Pulse	Segment 1 R1	Segment 1 R2	Segment 2 R3	Segment 2 R4	Segment 3 R5
1	A_1	B_1	-	-	-
2	A_2	B_2	$A_1 * B_1$	C_1	-
3	A_3	B_3	$A_2 * B_2$	C_2	$A_1 * B_1 + C_1$
4	A_4	B_4	$A_3 * B_3$	C_3	$A_2 * B_2 + C_2$
5	A_5	B_5	$A_4 * B_4$	C_4	$A_3 * B_3 + C_3$
6	A_6	B_6	$A_5 * B_5$	C_5	$A_4 * B_4 + C_4$
7	A_7	B_7	$A_6 * B_6$	C_6	$A_5 * B_5 + C_5$
8	-	-	$A_7 * B_7$	C_7	$A_6 * B_6 + C_6$
9	-	-			$A_7 * B_7 + C_7$

Fig :- Content of Register in Pipeline

- The general structure of four segment pipeline is as shown.



- The segments are ~~seg~~ separated by register R_i that hold the intermediate result between the stages.
- The behaviour of the pipeline can be illustrated by space time diagram. This shows the segment utilization as function of time.
- The space time diagram for four segment pipeline with six task is as shown

Segment	1	2	3	4	5	6	7	8	9
1	T_1	T_2	T_3	T_4	T_5	T_6			
2		T_1	T_2	T_3	T_4	T_5	T_6		
3			T_1	T_2	T_3	T_4	T_5	T_6	
4				T_1	T_2	T_3	T_4	T_5	T_6

fig :- Space time diagram for pipeline

• Pipeline Speed Up

→ Let n be number of task to be performed.

→ Let k be the number of segment pipeline with clock time tp.

→ Therefore, the first task T_1 requires time $= K * tp$

→ Now, remaining $(n-1)$ task $= (n-1) * tp$

So, to complete n task with K segment pipeline $= K + (n-1)$ clock cycles

→ For Non - Pipelined

Time required to complete each task $= tn$

Time required to complete n task $= n * tn$

$$\text{Speed Up} = \frac{n * tn}{K + (n-1)\ tp}$$

$$(\text{Speed Up})_{Max} = \frac{tn}{tp}$$

eg A non-pipelined system takes 50 ns to process a task. The same task process in six segment pipeline with clock cycle of 10 ns. Determine speed up ratio of pipeline for 100 tasks.

Soln:-

$t_n = 50$ ns

$k = 6$

$t_p = 10$ ns

$n = 100$

$$\text{Speed Up} = \frac{n * t_n}{(K + n - 1)\, t_p}$$

$$= \frac{100 * 50}{(6 + 100 - 1)\, 10}$$

$$= 4.76$$

$$(\text{Speed Up})_{Max} = \frac{t_n}{t_p}$$

$$= \frac{50}{10}$$

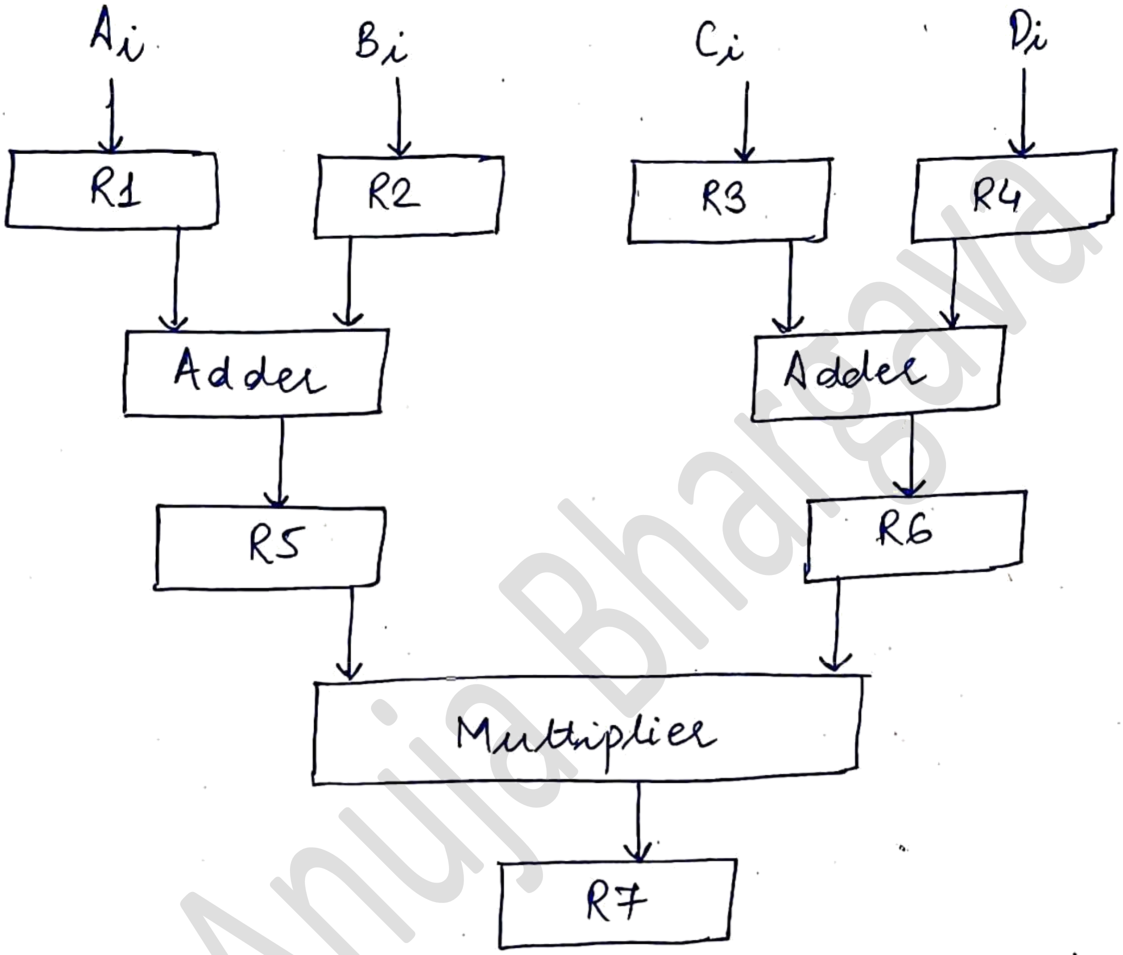
$$= 5$$

Q. The arithmetic operation $(A_i + B_i) * (C_i + D_i)$

a) Specify the pipeline configuration.

b) List the content of all registers in the pipeline for $i = 1$ to 6.

Soln:-



Clock Pulse	Segment 1				Segment 2		Segment 3
	R1	R2	R3	R4	R_5	R6	R7
1	A_1	B_1	C_1	D_1	-	-	-
2	A_2	B_2	C_2	D_2	$A_1 * B_1$	$C_1 * D_1$	-
3	A_3	B_3	C_3	D_3	$A_2 * B_2$	$C_2 * D_2$	$(A_1 * B_1) + (C_1 * D_1$
4	A_4	B_4	C_4	D_4	$A_3 * B_3$	$C_3 * D_3$	$(A_2 * B_2) + (C_2 * D_2$
5	A_5	B_5	C_5	D_5	$A_4 * B_4$	$C_4 * D_4$	$(A_3 * B_3) + (C_3 * D_3$
6	A_6	B_6	C_6	D_6	$A_5 * B_5$	$C_5 * D_5$	$(A_4 * B_4) + (C_4 * D_4$
7	-	-	-	-	$A_6 * B_6$	$C_6 * D_6$	$(A_5 * B_5) + (C_5 * D_5$
8	-	-	-	-	-	-	$(A_6 * B_6) + (C_6 * D_6$

Q Draw a space time diagram for six segment pipeline showing the time it takes to process eight task.

Soln:

Segment	1	2	3	4	5	6	7	8	9	10	11	12
1	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8				
2		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8			
3			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8		
4				T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
5					T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
6						T_1	T_2	T_3	T_4	T_5	T_6	T_7