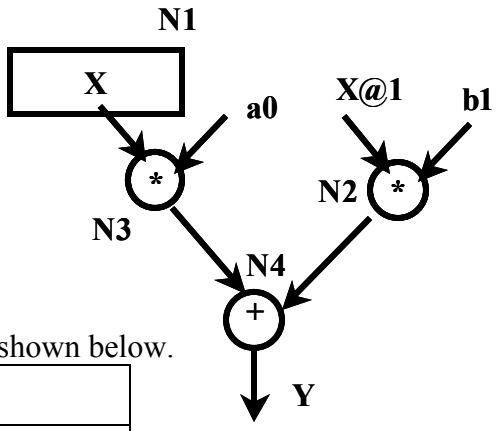
All problems refer to the following flowgraph (Y = x* a0 + x@1 * b1)

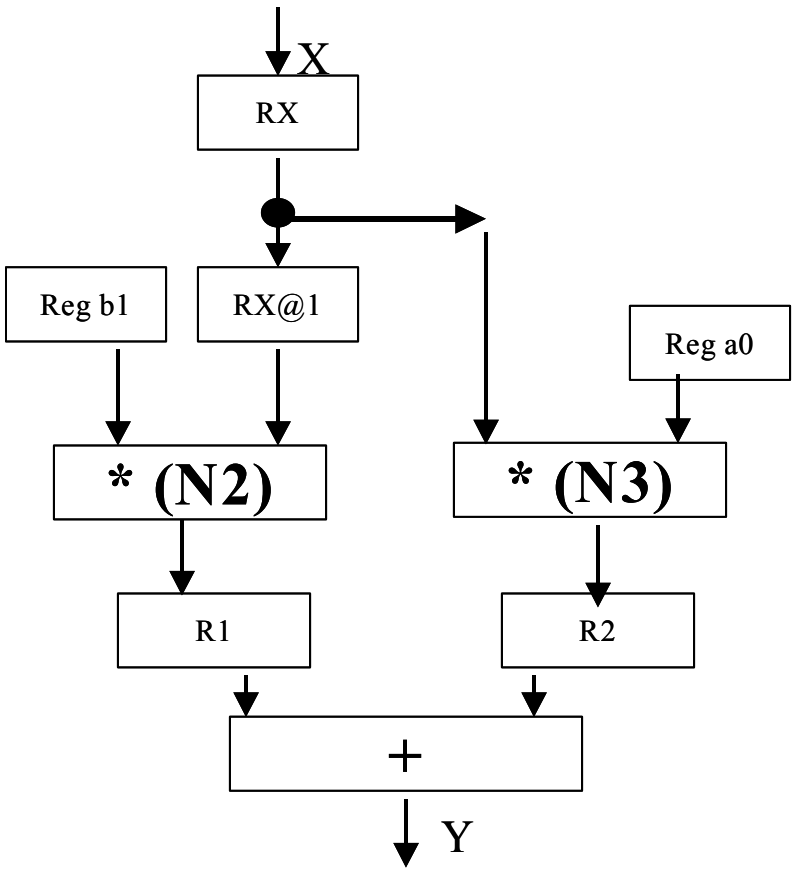
Figure 1



The schedule for initiation rate = 1, latency =3 and datapath is shown below.

	Sample A	Sample B	Sample C
Clk N	N1(←)		
Clk N+1	N2(*), N3(*)	N1(←)	
Clk N+2	N4(+)	N2(*), N3(*)	N1(←)
Clk N+3		N4(+)	N2(*), N3(*)
Clk N+4			N4(+)

Datapath A



1. Assume the multiplier now has a pipeline stage, and apply this to the schedule on the previous page.

What happens to the latency?

	Sample A	Sample B	Sample C	Sample D	Sample E
Clk N	N1(←)				
Clk N+1	N2(*),N3(*)	N1(←)			
Clk N+2		N2(*),N3(*)	N1(←)		
Clk N+3	N4(+)		N2(*),N3(*)	N1(←)	
Clk N+4		N4(+)		N2(*),N3(*)	N1(←)
Clk N+5			N4(+)		N2(*),N3(*)
Clk N+6				N4(+)	
Clk N+7					N4(+)

Does the datapath need to change other than replacing the multiplier with a pipelined multiplier? Why or Why not?

No, it does not need to change since the pipeline stages add the same latency to every path.

2. *Assume the delay of the multiplier is 20 ns, the adder delay is 7 ns, Tsu = 1 ns, Thd = 1 ns, TCq = 2ns*

A1. What is the minimum clock period of the original datapath?
Tmult + Tcq + Tsu = 20 + 2 + 1 = 23 ns

A2. How long does it take to compute the first 10 sample values? Include pipeline startup.

3 clocks for 1 sample, then 9 clocks after that. 3 * 23 + 9*23 = 276 ns

B1. What is the minimum clock period of the new datapath with the pipelined multiplier?

Tmult/2 + Tcq + Tsu = 10 + 2 + 1 = 13 ns

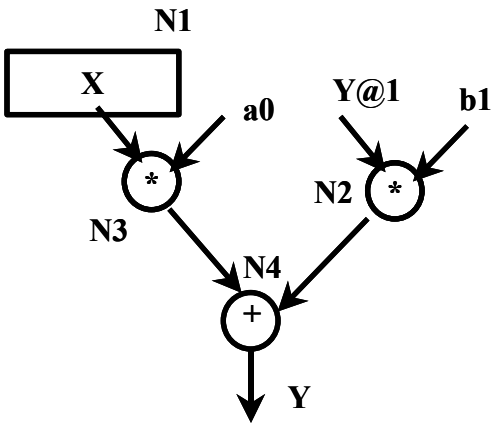
How long does it take to compute 10 sample values?

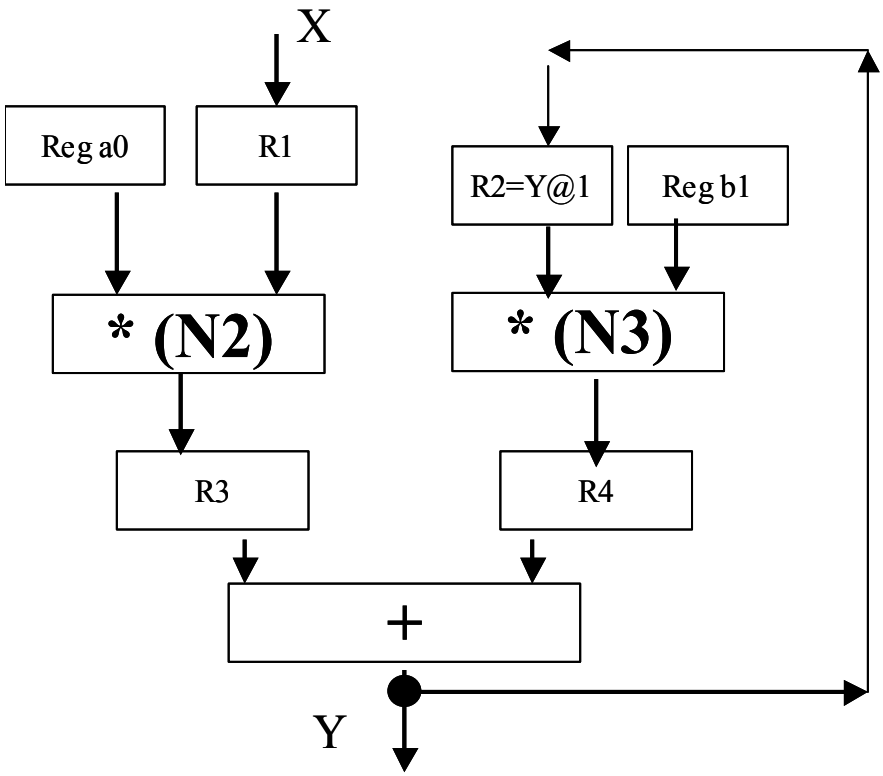
4 clocks for 1 sample, 9 clocks after that : 4 * 13 + 9 * 13 = 169 ns.

The schedule for flowgraph with the Y @1 input value is shown below.

	Sample J	*Sample J+1*
Clk 1	*N1*	
Clk 2	*N3, N2 (depends on N4 Sample J-1)*	
Clk 3	*N4*	*N1,*
Clk 4		***N3, N2 (depends on N4 sample J)***
Clk 5		*N4*
Clk 6		

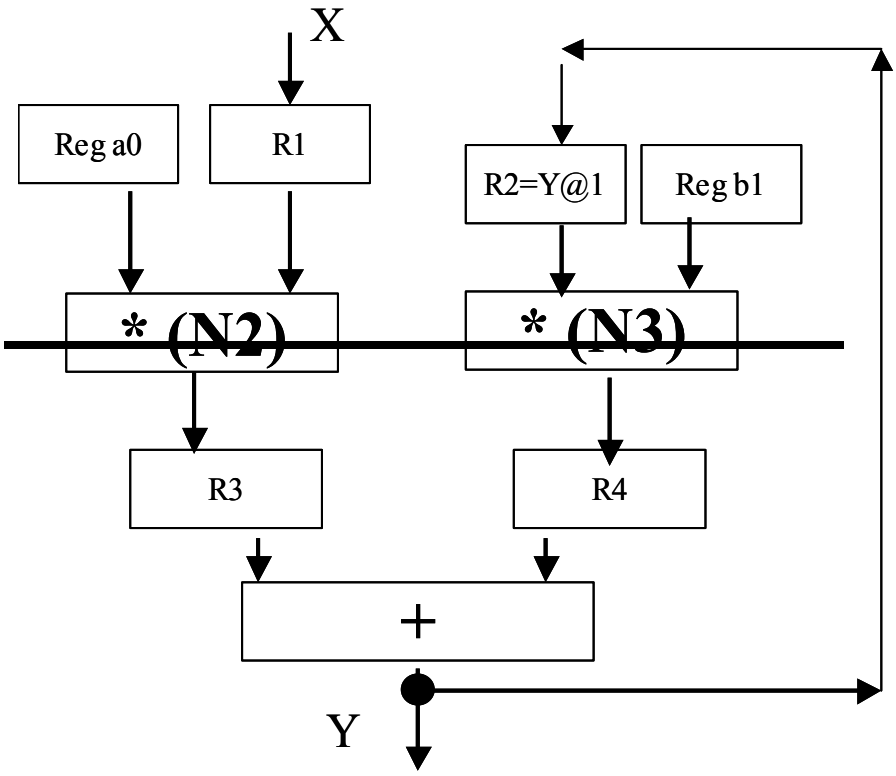
Figure 2





3. Assume the multiplier now has a pipeline stage, and create a new schedule. What happens to initiation rate, latency?

	Sample A	Sample B	Sample C	Sample D	Sample E
Clk N	N1				
Clk N+1	N3, N2				
Clk N+2	↓				
Clk N+3	N4 ↘	N1			
Clk N+4		N3,N2			
Clk N+5		↓			
Clk N+6		N4			
Clk N+7					



4. Assume the delay of the multiplier is 20 ns, the adder delay is 7 ns, Tsu = 1 ns, Thd = 1 ns, TCq = 2ns

A1. What is the minimum clock period of the original datapath (without pipelining)?

Tmult + Tcq + Tsu = 20 + 2 + 1 = 23 ns

A2. How long does it take to compute the first 10 sample values (without a pipelined multiplier)? Include datapath startup.

3 clocks for first sample, then 9*2 clocks after that. 3 * 23 + 9*2*23 = 483 ns

B1. What is the minimum clock period of the new datapath with the pipelined multiplier?

Tmult/2 + Tcq + Tsu = 10 + 2 + 1 = 13 ns

How long does it take to compute 10 sample values?

4 clocks for first sample, then 9*3 clocks after that. 4 * 13 + 9*3*13 = 403 ns

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