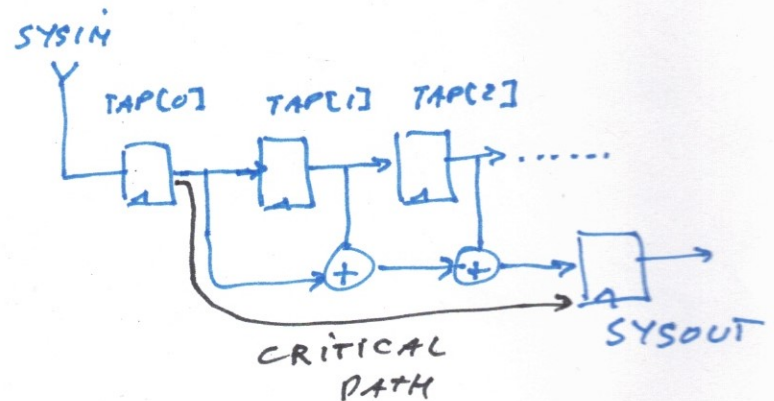


```

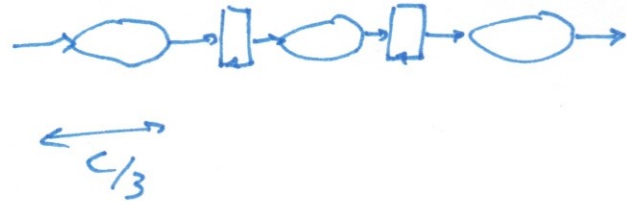
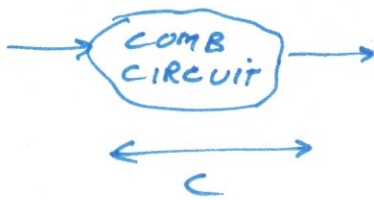
1  module fir(
2      input          CLOCK_50,
3      input [3:0]    KEY,
4      output [9:0]   LEDR,
5      input [9:0]    SW
6  );
7
8  `define TAP 16
9
10     reg [9:0] sysin, sysout, sysout_next;
11     reg [9:0] tap[TAP-1:0], tap_next[TAP-1:0];
12     reg [9:0] acc[TAP-1:0];
13     integer i;
14
15     always @(posedge CLOCK_50)
16     begin
17         sysout <= KEY[0] ? sysout_next : 10'b0;
18         for (i = 0; i < TAP; i = i + 1)
19             tap[i] <= KEY[0] ? tap_next[i] : 10'b0;
20     end
21
22
23     always @(*)
24     begin
25         sysin = SW[9:0];
26
27         tap_next[0] = sysin;
28         for (i = 1; i < TAP; i = i + 1)
29             tap_next[i] = tap[i-1];
30
31         acc[0] = tap[0];
32         for (i = 1; i < TAP; i = i + 1)
33             acc[i] = acc[i-1] + tap[i];
34
35         sysout_next = acc[15];
36     end
37
38     assign LEDR = sysout;
39
40 endmodule
41
42

```



PIPELINING:

①



LATENCY:

$$C \text{ (s)}$$

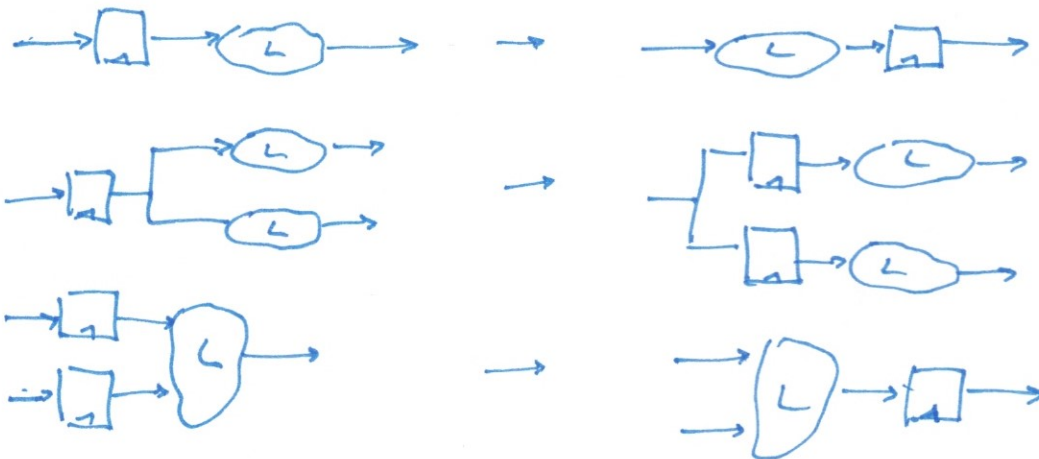
$$\frac{C}{3} \cdot 3 \text{ (s)}$$

THROUGHPUT:

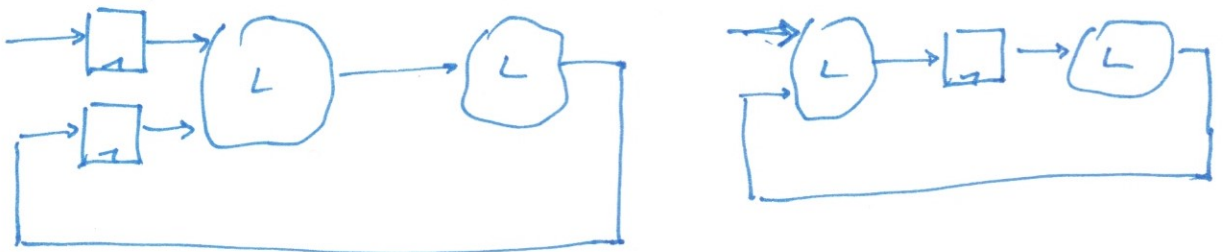
$$C^{-1} \text{ (s}^{-1}\text{)}$$

$$3 \cdot C^{-1} \text{ (s}^{-1}\text{)}$$

RETIMING:

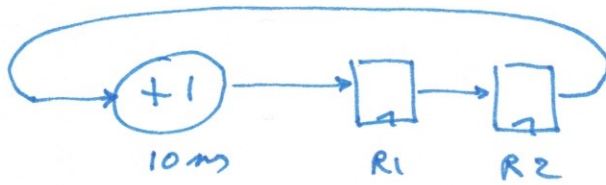


EXAMPLE:



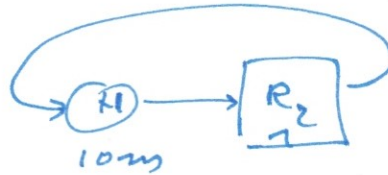
VHFOLDING

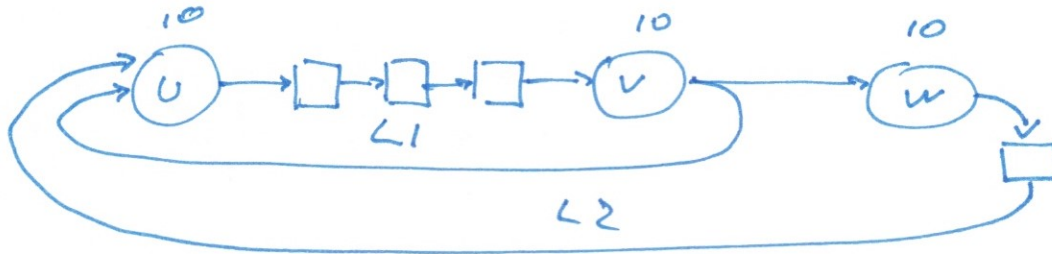
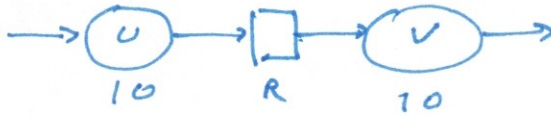
(2)



$$t_{\text{cair}} = 10\text{ms}.$$

	R1	R2
CYCLED	0	0
1	1	0
2	1	1
3	2	1
4	2	2
5	3	2
6	3	3





$$\text{LOOP BOUND} = \frac{\sum \text{COMB DELAYS}}{\# \text{ REGISTERS}}$$

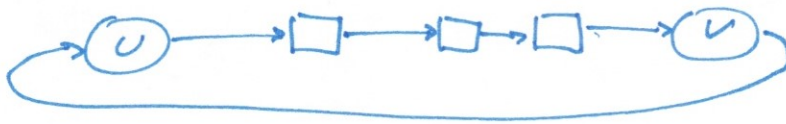
$$L1: \frac{10+10}{3} = \frac{20}{3} = 6.6$$

$$L2: \frac{10+10+10}{4} = \frac{30}{4} = 7.5$$

$$\text{ITERATION BOUND} = \text{MAX}(\text{LOOP BOUND})$$

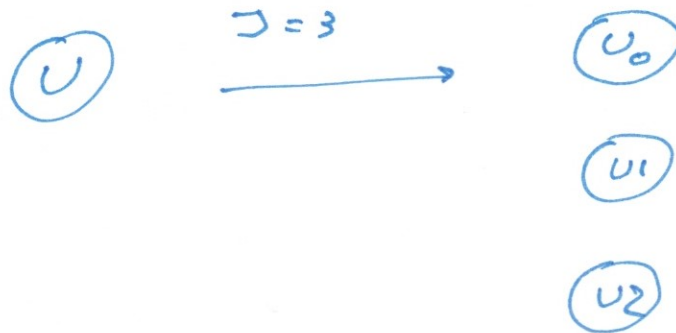
RULES FOR UNFOLDING

④



UNFOLD IT J TIMES

1) DUPLICATE EVERY NODE J TIMES



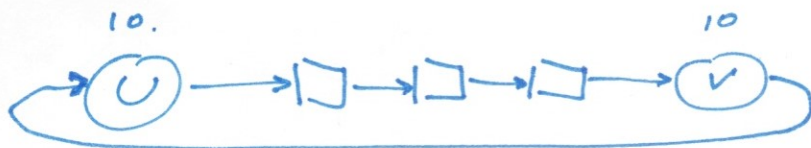
2) CONNECT EDGES.



J connections: $i: 0 \dots J-1$

a) U_i to $V_{(i+w) \% J}$

b) ADD $\lfloor \frac{(i+w)}{J} \rfloor$ REGISTERS



$w = 3$

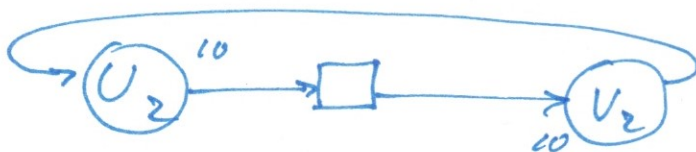
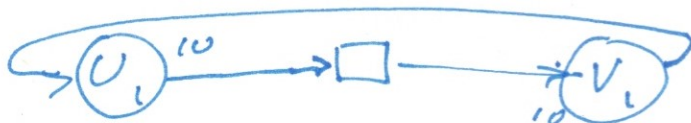
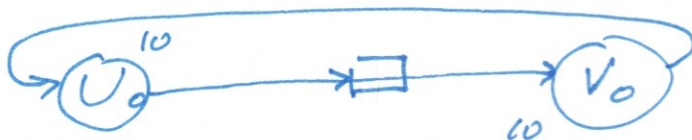
UNFOLD 3X

↑
ONE OUTPUT
EVERY 20

$\square = 3$

$$U_i \rightarrow V_{(i+w) \% \square}$$

$$\# \text{ REG: } \left\lfloor \frac{L+w}{3} \right\rfloor$$

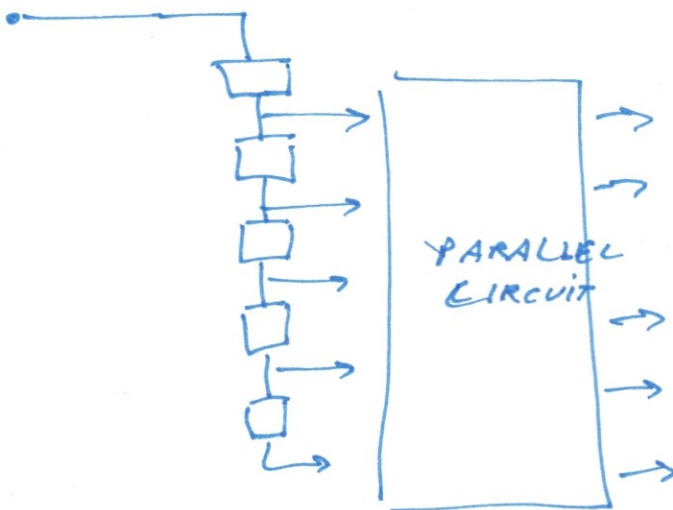


↑

3 OUTPUTS
EVERY 20

ULTRA HIGH SPEED.

SERIAL



AREA - TIME TRADE OFF

6

