

Fig. 4.18 A 6th-order orthogonal filter for Problem 4.

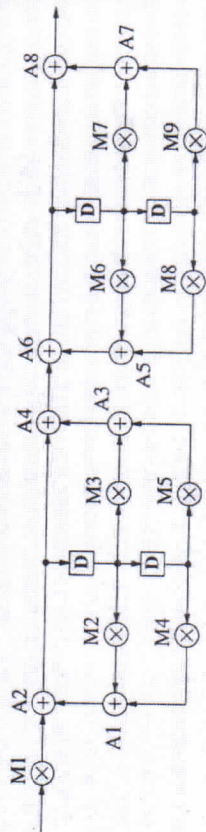


Fig. 4.19 The DFG for the 4th-order IIR filter in Problem 5.

achieve a critical path of computation $2T$ nsec. Show all the cutset locations used for retiming explicitly.

5. The DFG shown in Fig. 4.19 describes a 4th-order IIR digital filter implemented as cascade of 2 2nd-order sections. Assume each multiply requires 2 u.t. and add requires 1 u.t.

- What is the critical path of this DFG? What is the iteration bound of this DFG?
- Manually retime and pipeline the DFG to minimize the clock period. What is the minimum achievable clock period obtained with pipelining and retiming?

6. For the biquad filter in Fig. 4.20, assume that addition and multiplication require 1 and 2 u.t., respectively. There are 120 unique retiming solutions that retime this filter to have a clock period of 4 u.t. Find 10 of these solutions by inspection.

7. For the DFG in Fig. 4.20, find the retimed DFG for $r(1) = 0$, $r(2) = 0$, $r(3) = -1$, $r(4) = -2$, $r(5) = -1$, $r(6) = 0$, $r(7) = 0$, and $r(8) = 0$.

8. Draw a constraint graph and use it to determine if the following system of inequalities has a solution, and find a solution if one exists using

- the Bellman-Ford algorithm, and
- the Floyd-Warshall algorithm.

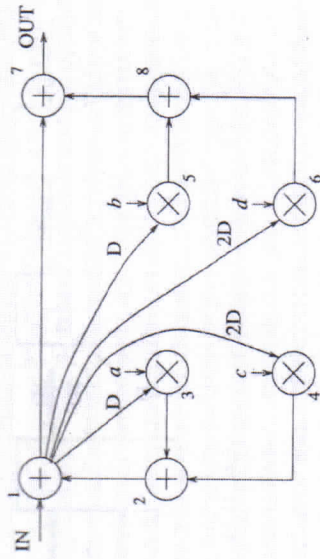


Fig. 4.20 The biquad filter. The numbers next to the nodes are node labels used in Problem 7, not execution times.

$$\begin{aligned} r_1 - r_2 &\leq 1 \\ r_3 - r_1 &\leq 3 \\ r_4 - r_1 &\leq 2 \\ r_4 - r_3 &\leq -1 \\ r_3 - r_2 &\leq 1 \\ r_5 - r_1 &\leq 2 \\ r_3 - r_5 &\leq -1 \\ r_4 - r_5 &\leq -2. \end{aligned}$$

9. Draw a constraint graph and use it to determine if the following system of inequalities has a solution, and find a solution if one exists using

- the Bellman-Ford algorithm, and
- the Floyd-Warshall algorithm.

$$\begin{aligned} r_1 - r_2 &\leq 1 \\ r_3 - r_1 &\leq 3 \\ r_4 - r_1 &\leq 2 \\ r_4 - r_3 &\leq -1 \\ r_3 - r_2 &\leq 1 \\ r_5 - r_1 &\leq 2 \\ r_3 - r_5 &\leq -6 \\ r_4 - r_5 &\leq -2. \end{aligned}$$

10. Retime/pipeline the IIR digital filter shown in Fig. 3.21 (see Problem 2 of Chapter 3) to reduce the critical path to 2 time units.