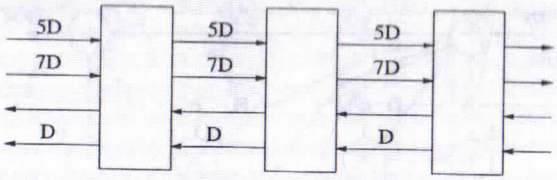

Fig. 4.21 The recursive DFG used in Problem 11(a).

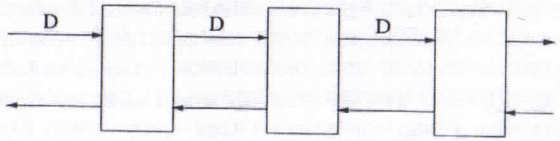

Fig. 4.22 The recursive DFG used in Problem 11(b).

11. This problem addresses interblock pipelining of recursive DFGs.

    (a) Retime the system shown in Fig. 4.21 to achieve interblock pipelining, i.e., each interblock communicating edge should have at least one delay element.

    (b) To obtain interblock pipelining for the system shown in Fig. 4.22, use an appropriate slow-down approach and then use retiming. What is the hardware utilization efficiency of this system?

12. Consider the N-stage normalized lattice filter in Fig. 4.23. Let $N = 25$, i.e., the filter has 25 modules, and assume that addition and multiplication take 1 and 2 u.t., respectively.

    (a) Compute the critical path and the minimum clock period for this filter.

    (b) Using a 2-slow transformation, retime the filter so that it is pipelined at the module level, i.e., each wire between modules has at least one delay. What is the clock period and sample period of the retimed filter?

13. The objective of this problem is to write a program to retime a DFG for clock period minimization. Assume that addition and multiplication require 1 and 2 u.t., respectively. Formulate the constraints for retiming and use your program to determine the minimum clock period for the direct-form 3rd-order IIR filter in Fig. 4.24.

14. Repeat Problem 13 for the DFG in Fig. 4.25, which represents a 5th-order wave digital elliptic filter.

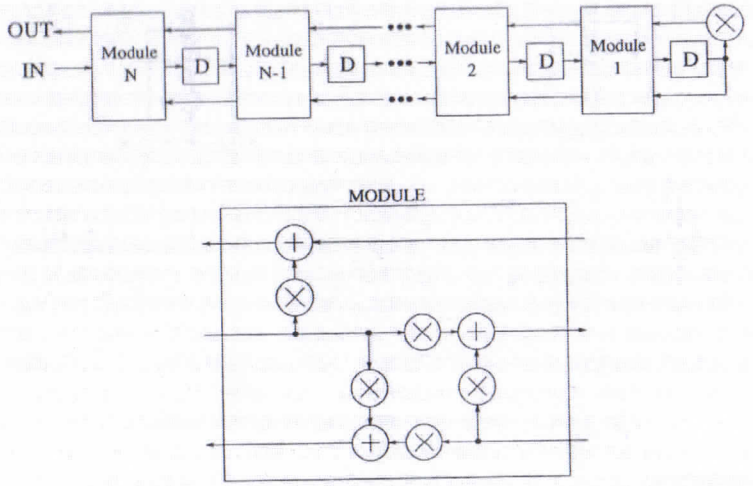

Fig. 4.23 The N-stage normalized lattice filter.

15. Repeat Problem 13 for the DFG in Fig. 2.17, which represents a 1-multiplier basic lattice IIR digital filter.

16. Systematically retime the DFG used in Problem 13 to minimize the number of registers while achieving a clock period of 4 u.t. Assume that addition and multiplication require 1 and 2 u.t., respectively.

17. Systematically retime the DFG used in Problem 3 to minimize the number of registers while achieving a clock period of 2 u.t. Assume that addition and multiplication require 1 and 2 u.t., respectively.

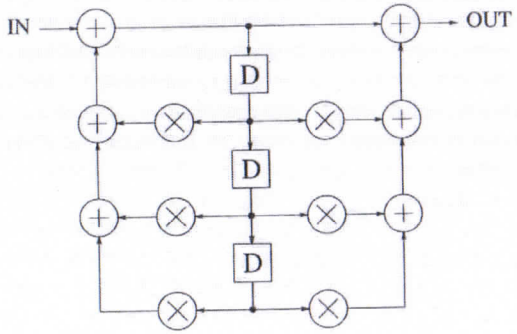

Fig. 4.24 Direct-form 3rd-order IIR filter.