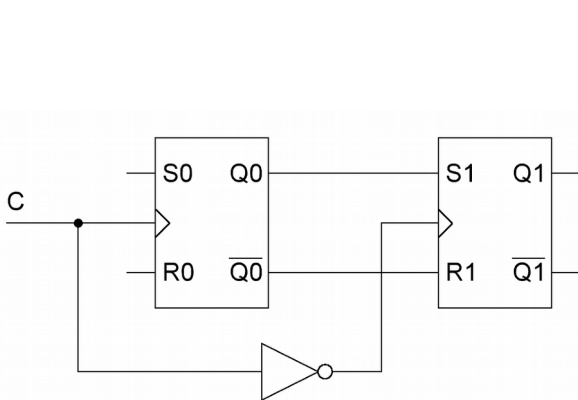


Key to Tutorial 3

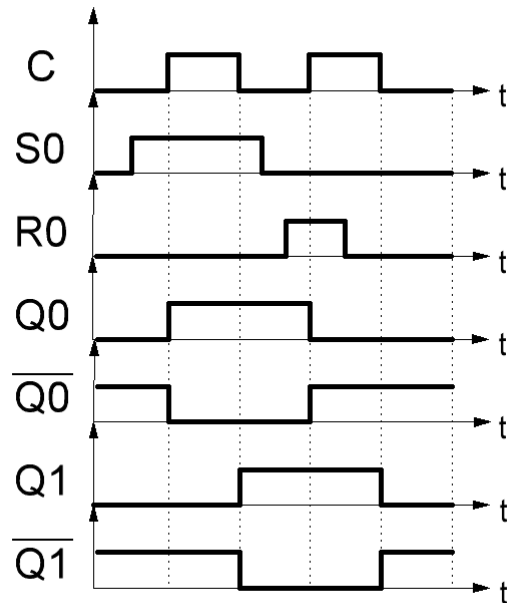
Flip-Flops

Exercise 1: RS Flip-Flops

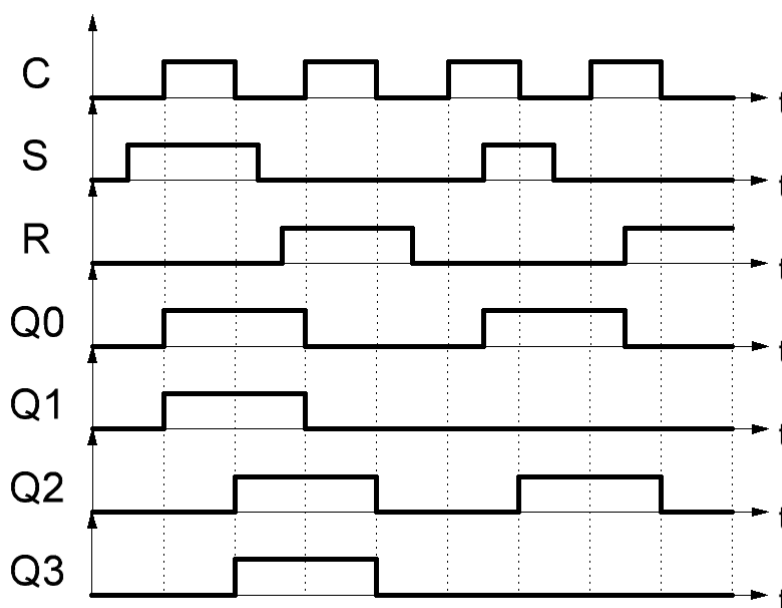
- Complete the timing diagram for the circuit below. If we consider the whole circuit as only one RS flip-flop, in what way is this flip-flop clocked?



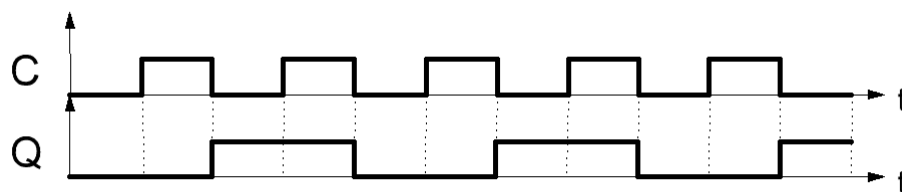
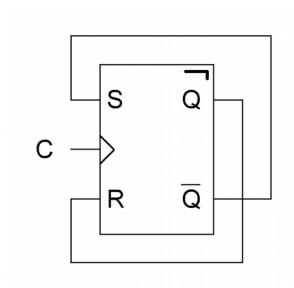
This circuit is a master-slave RS flip-flop.



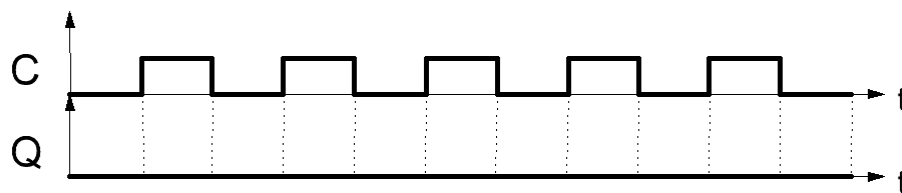
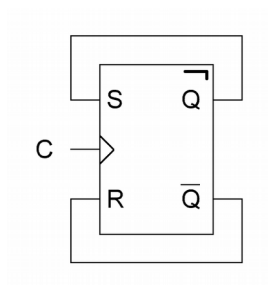
- Complete the following timing diagrams for a gated RS latch ($Q0$), a positive-edge-triggered RS flip-flop ($Q1$), a negative-edge-triggered RS flip-flop ($Q2$) and a master-slave RS flip-flop ($Q3$).



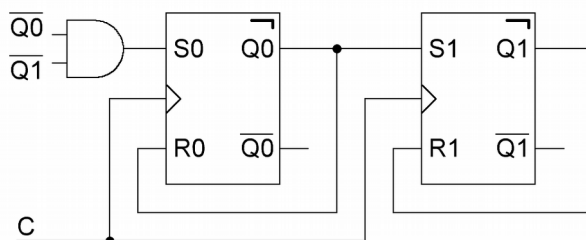
3. Draw the timing diagram of the Q output for each of the two circuits below. What is the frequency ratio between C and the Q output of the first circuit? What is this circuit called?

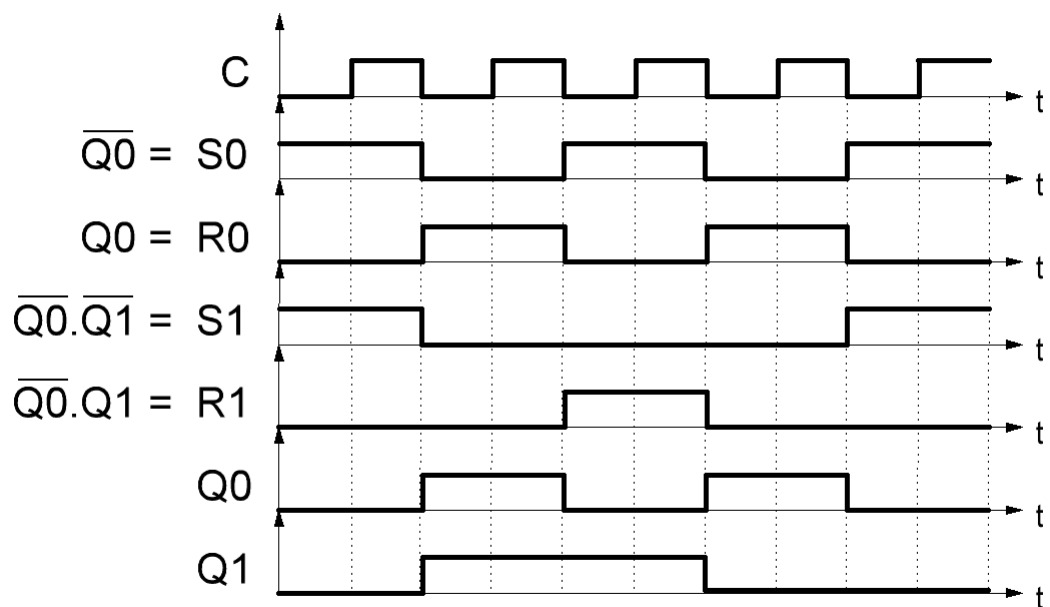
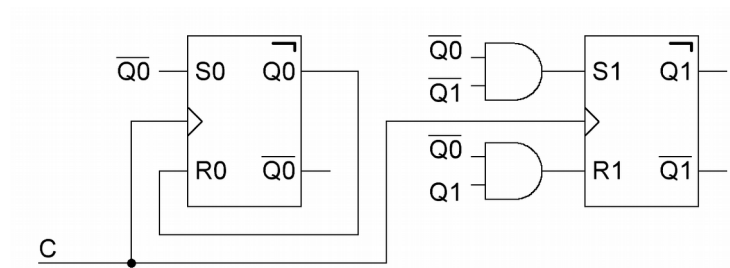
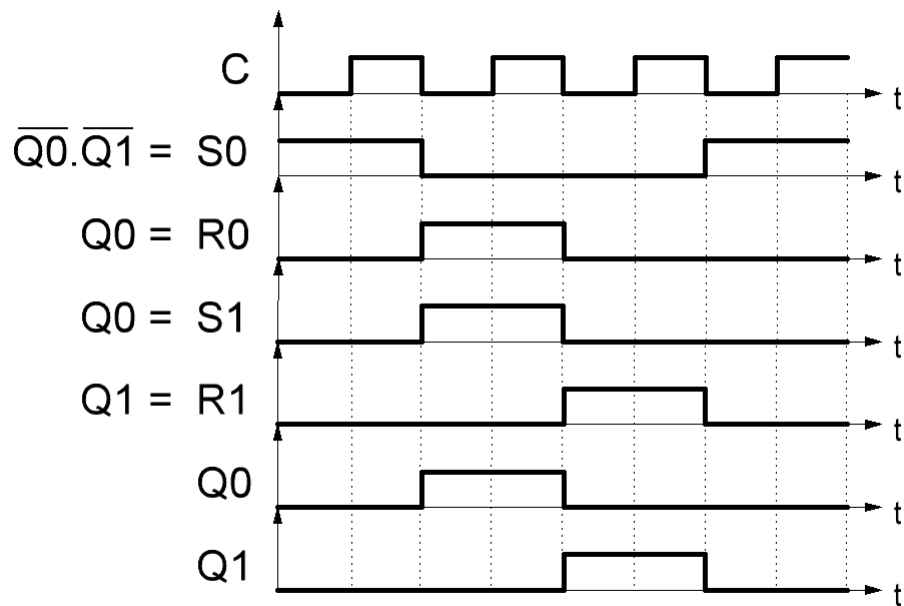


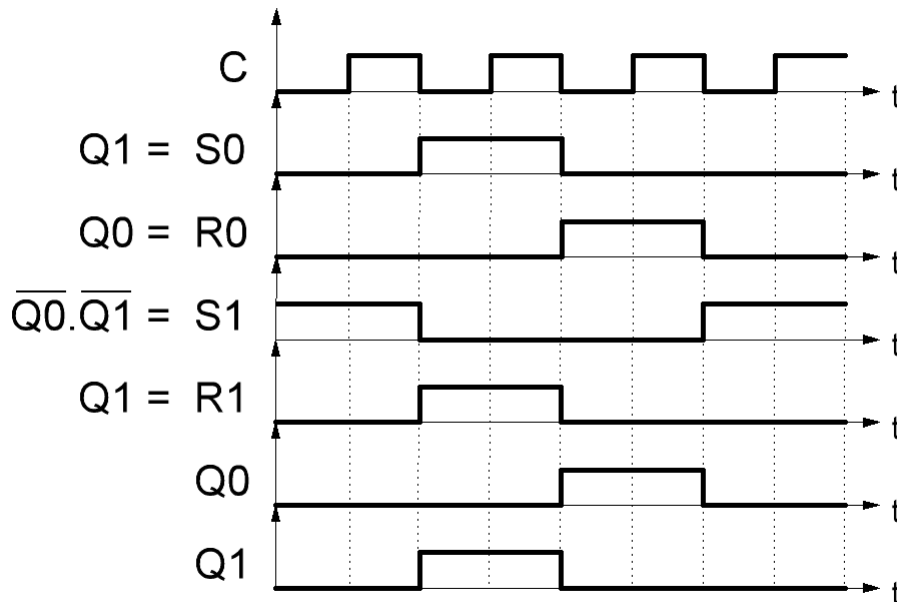
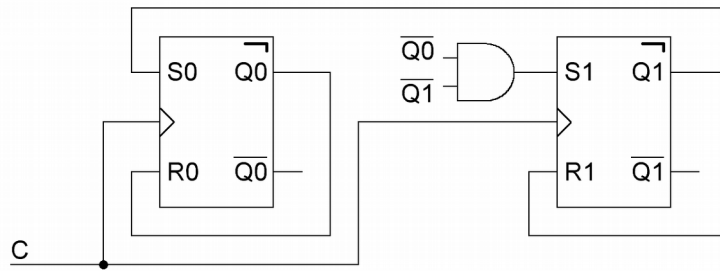
$$f_Q/f_C = 1/2 \rightarrow \text{Divide-by-two circuit}$$



4. Complete the timing diagrams for the circuits below.

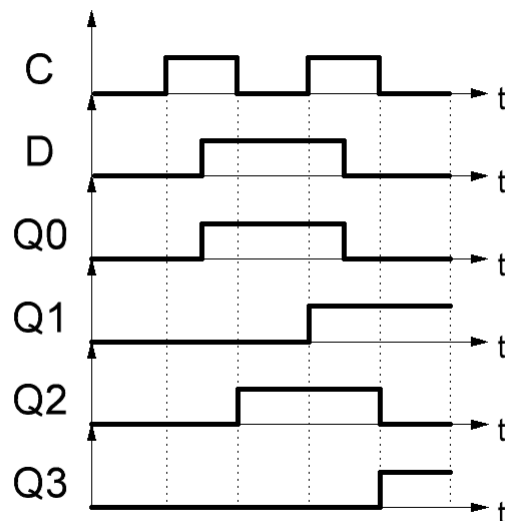
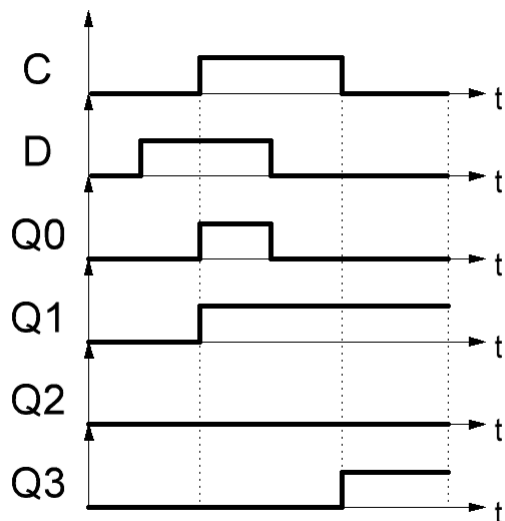




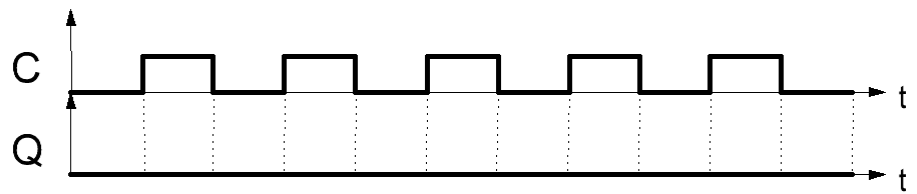
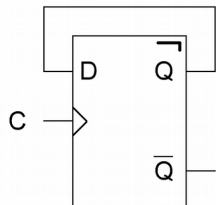
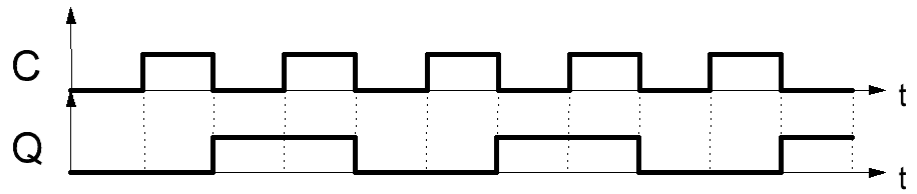
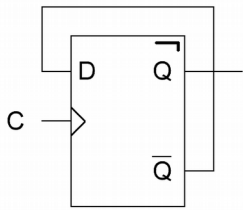


Exercise 2: D Flip-Flops

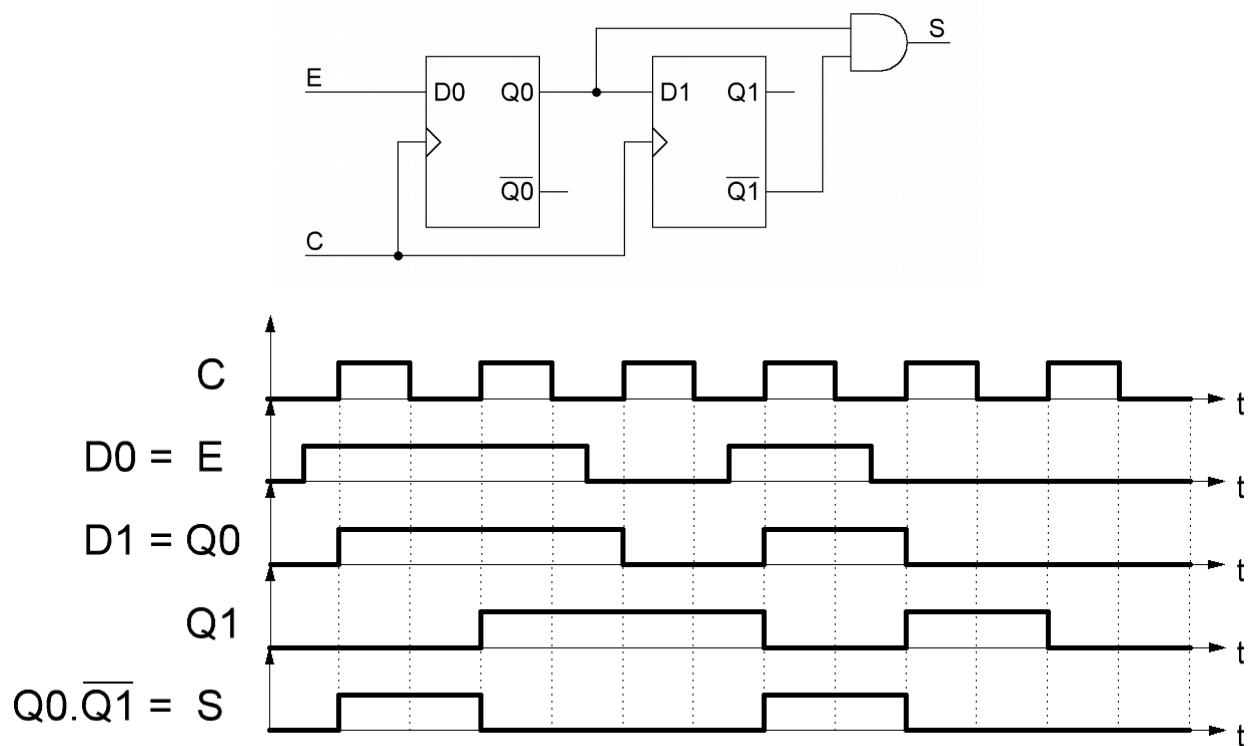
- Complete the following timing diagrams for a gated D latch ($Q0$), a positive-edge-triggered D flip-flop ($Q1$), a negative-edge-triggered D flip-flop ($Q2$) and a master-slave D flip-flop ($Q3$).



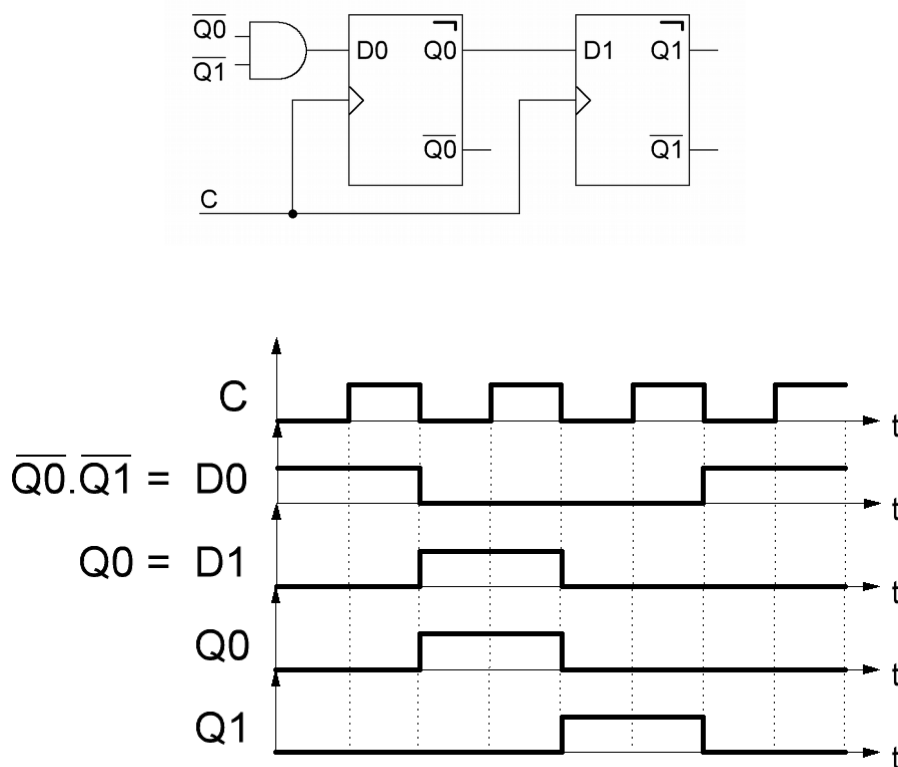
- Draw the timing diagram of the Q output for each of the two circuits below.

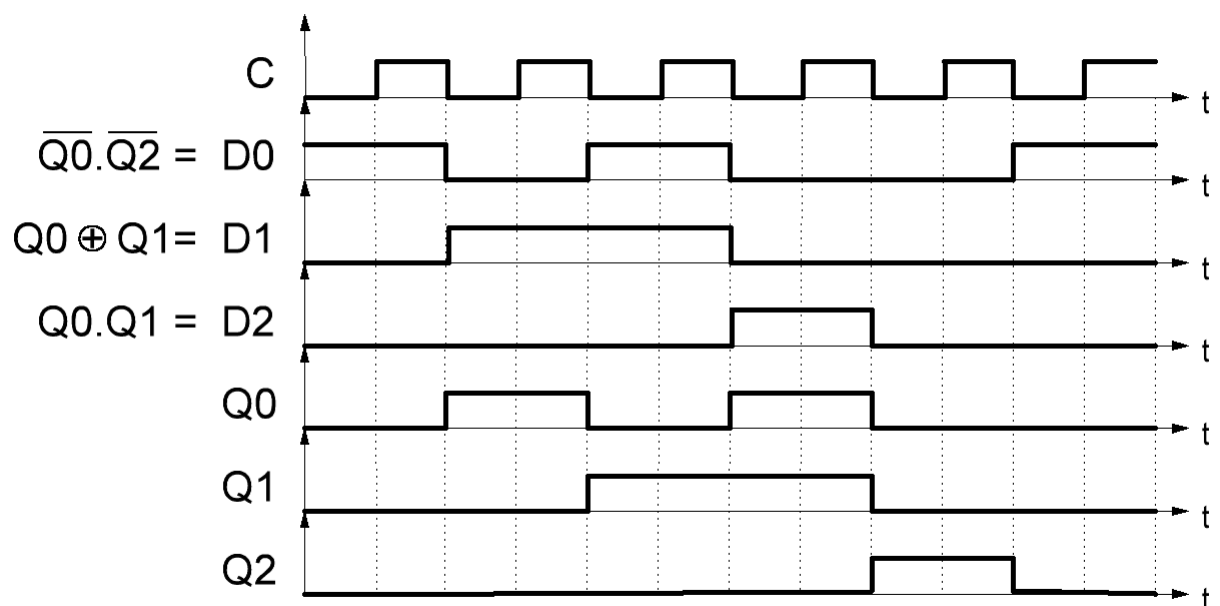
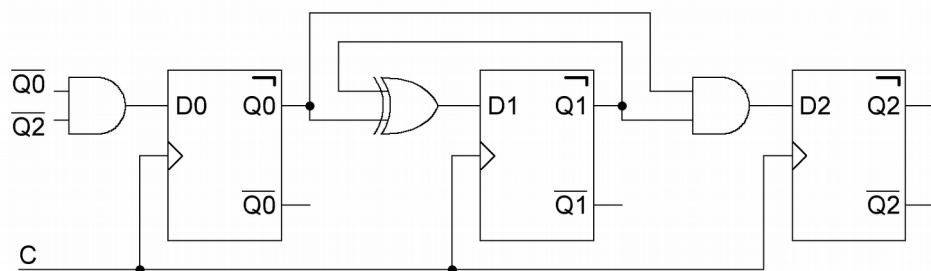
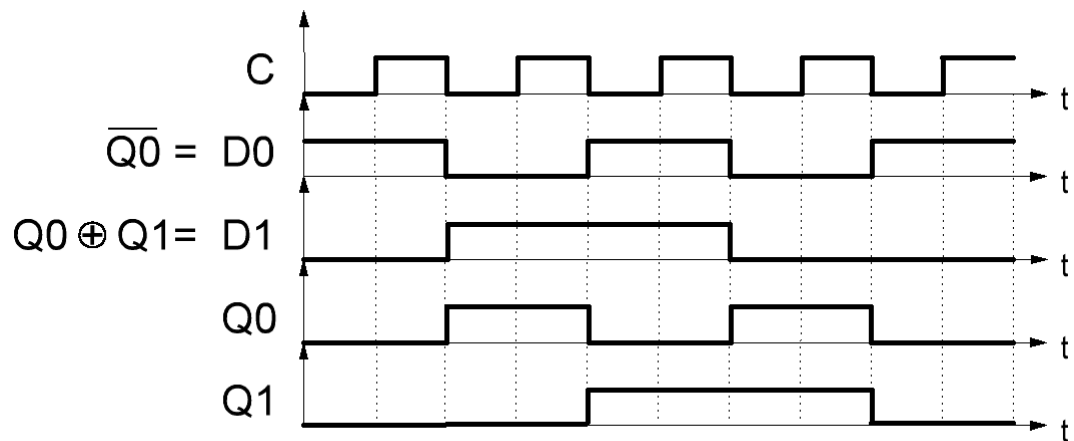
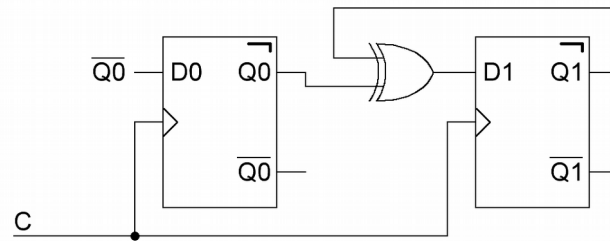


3. Complete the timing diagram for the following circuit.



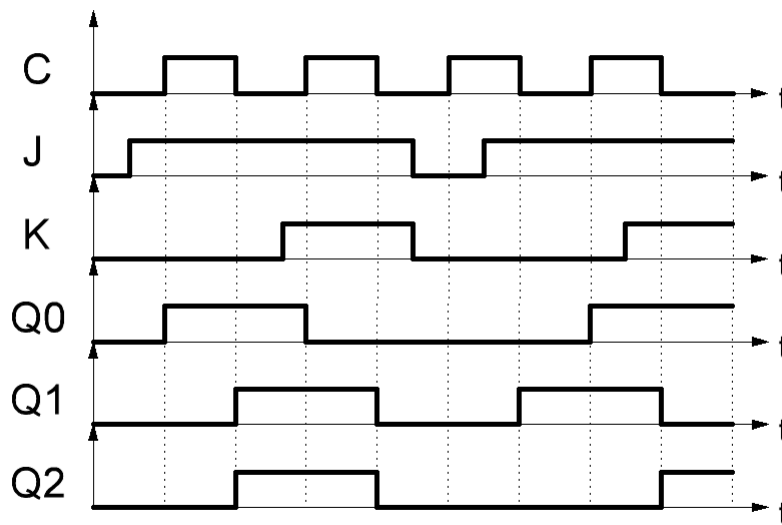
4. Complete the timing diagrams for the circuits below.



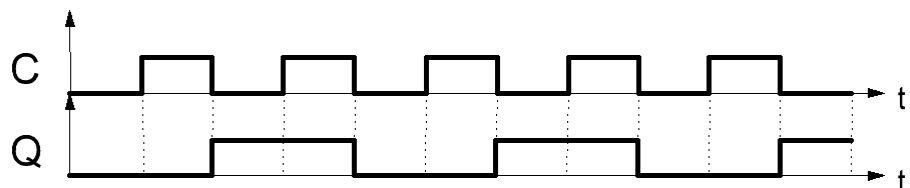
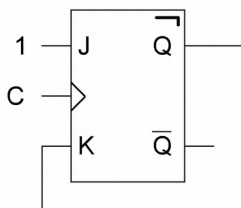
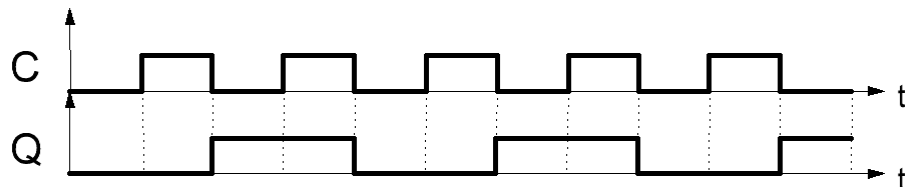
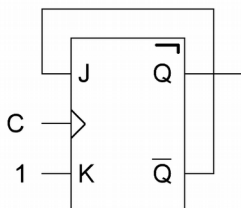


Exercise 3: JK Flip-Flops

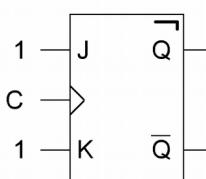
1. Complete the following timing diagrams for a positive-edge-triggered JK flip-flop ($Q0$), a negative-edge-triggered JK flip-flop ($Q1$) and a master-slave JK flip-flop ($Q2$).



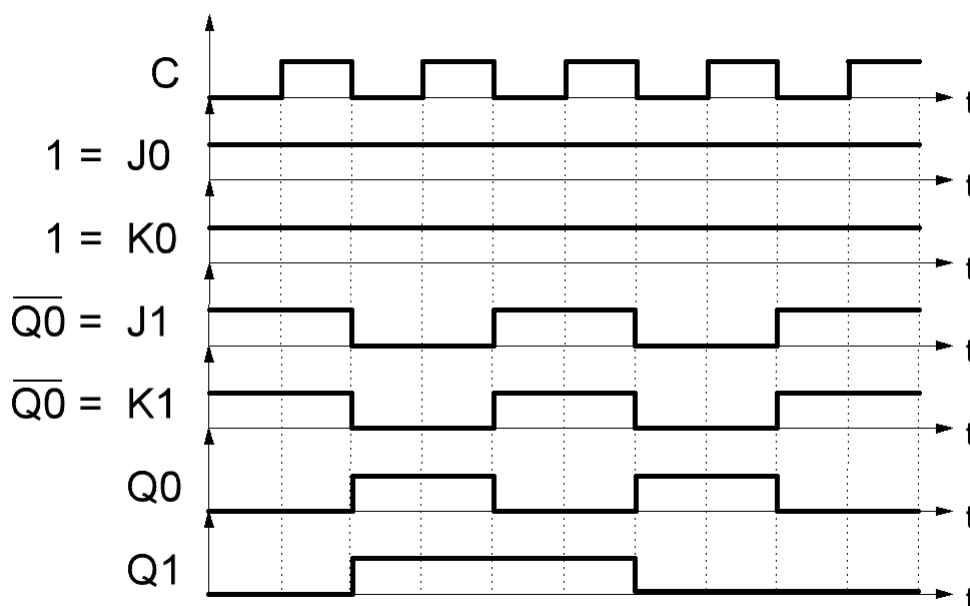
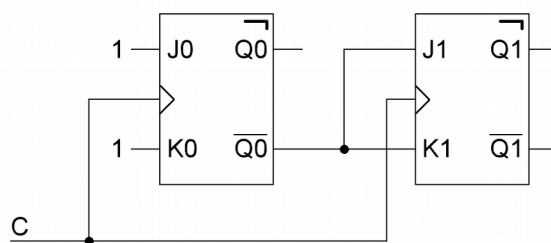
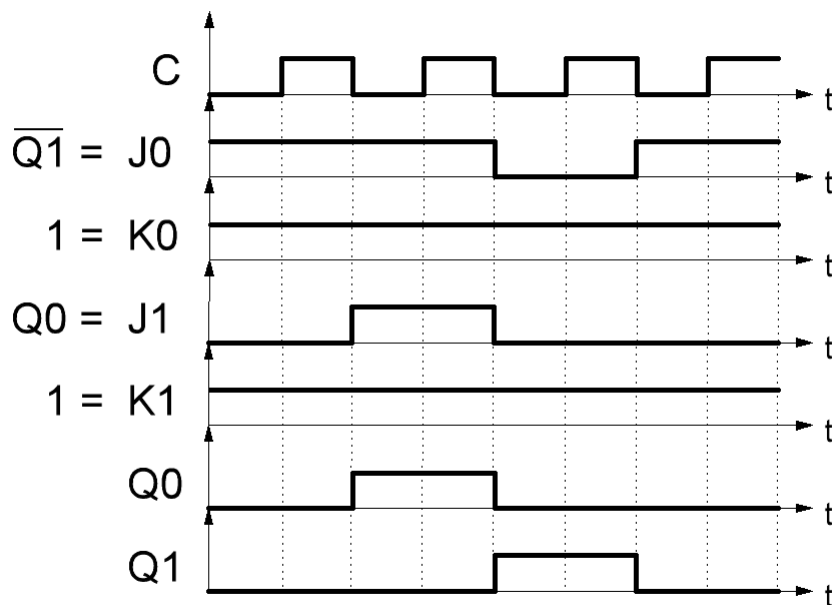
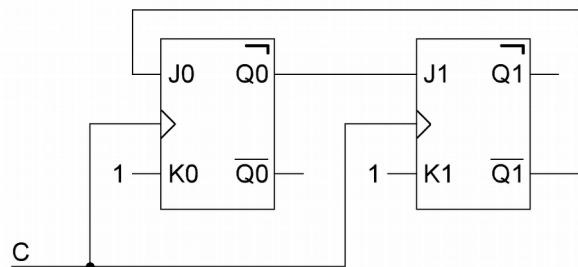
2. Draw the timing diagram of the Q output for each of the two circuits below. What is the frequency ratio between C and Q ? What are these circuits called? Find another way to get the same frequency ratio.

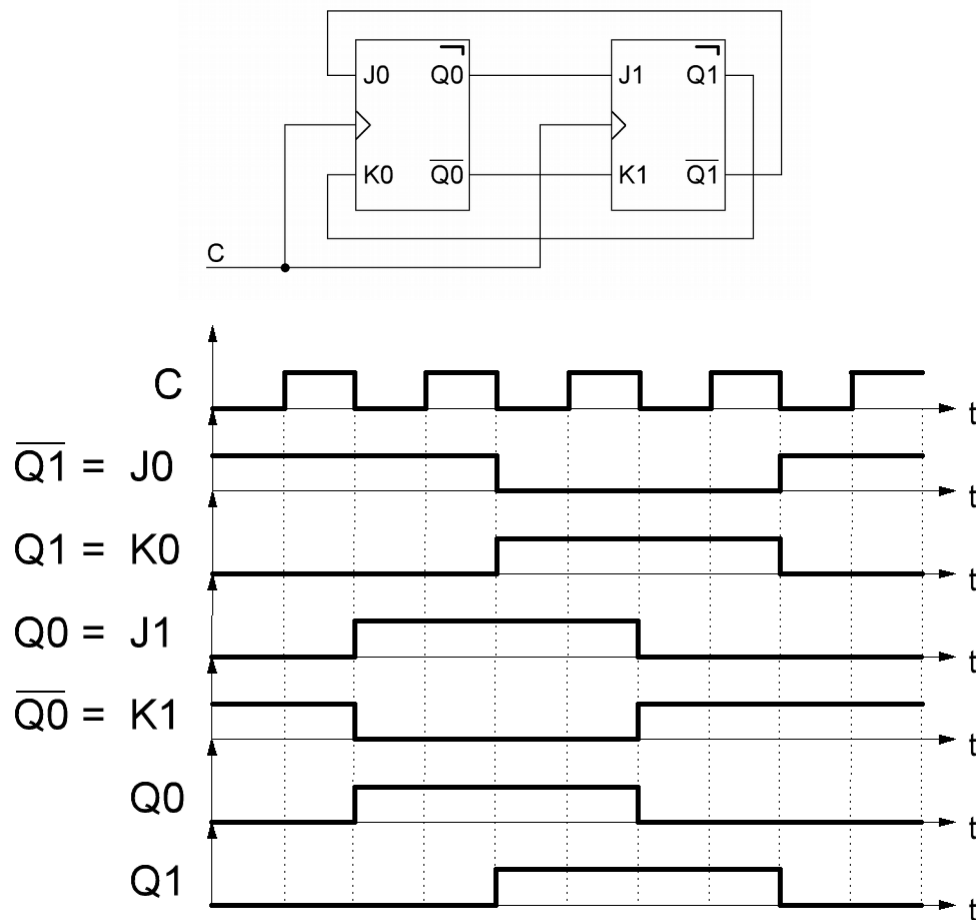


$f_Q/f_C = 1/2 \rightarrow$ Divide-by-two circuit

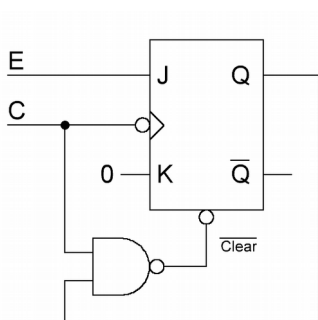


3. Complete the timing diagrams for the circuits below.





4. Complete the timing diagram for the circuit below.



5. Complete the timing diagram for the circuit below.

