Synchronous counters

Exercises Digital Design

1 | CNT - Counters by a power of 2

1.1 Downwards Counter

Using D flip-flops and combinational logic gates, create a synchronous down-counter with the sequence

$$15 \Rightarrow 14 \Rightarrow 13 \Rightarrow 12 \Rightarrow ...3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 0 \Rightarrow 15 \Rightarrow 14 \Rightarrow ... \quad (1)$$

Draw the complete schema.

cnt/pow2-01

1.2 Downwards Counter

Use T flip-flops and NAND gates to create a synchronous down-counter with the sequence

$$7 \Rightarrow 6 \Rightarrow 5 \Rightarrow 4 \Rightarrow 3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 0 \Rightarrow 7 \Rightarrow 6 \Rightarrow ... \quad (2)$$

Draw the complete schema.

cnt/cnt-pow2-02

2 | CNT - Counters by any number

2.1 Downwards Counter

Using D flip-flops and NAND gates, create a modulo-10 synchronous down-counter with the sequence

$$9 \Rightarrow 8 \Rightarrow 7 \Rightarrow 6 \Rightarrow \ldots 3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 0 \Rightarrow 9 \Rightarrow 8 \Rightarrow \ldots \tag{3}$$

Draw the complete schema.
Draw the state graph with all states, including those outside the main loop.

cnt/cnt-01

2.2 Downwards Counter

Use D flip-flops and multiplexers to create a synchronous down-counter with the sequence

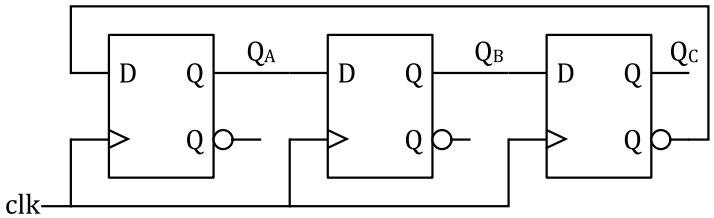
$$6 \Rightarrow 5 \Rightarrow 4 \Rightarrow 3 \Rightarrow 2 \Rightarrow 6 \Rightarrow \ldots \tag{4}$$

Draw the complete circuit.

cnt/cnt-02

2.3 Johnson Counter

The following figure shows a Johnson counter.



This type of counter is of interest for high-speed systems. The circuit has one disadvantage: it has two independent sequences.
Eliminate the shortest sequence by changing the input function D_B of the second flip-flop.

cnt/cnt-03

3 CNT - Iterative circuits

3.1 Counter with Synchronous Zeroing

Use D flip-flops and NAND gates to create a 4-bit counter with synchronous zero setting.
The counter has a control input **`restart`**. If **`restart='1'`**, the circuit sets itself to zero at the next active clock edge. If **`restart='0'`**, the circuit counts upwards.

cnt/cnt-iterativ-01

3.2 Counter with loading of a value

With the help of D flip-flops and NAND gates, you can create a 4-bit counter in which a new value can be loaded.
The counter has a control input **`load`** and a 4-bit data input. If **`load='1'`**, the circuit loads the data input. If **`load='0'`**, the circuit counts upwards.

cnt/cnt-iterativ-02

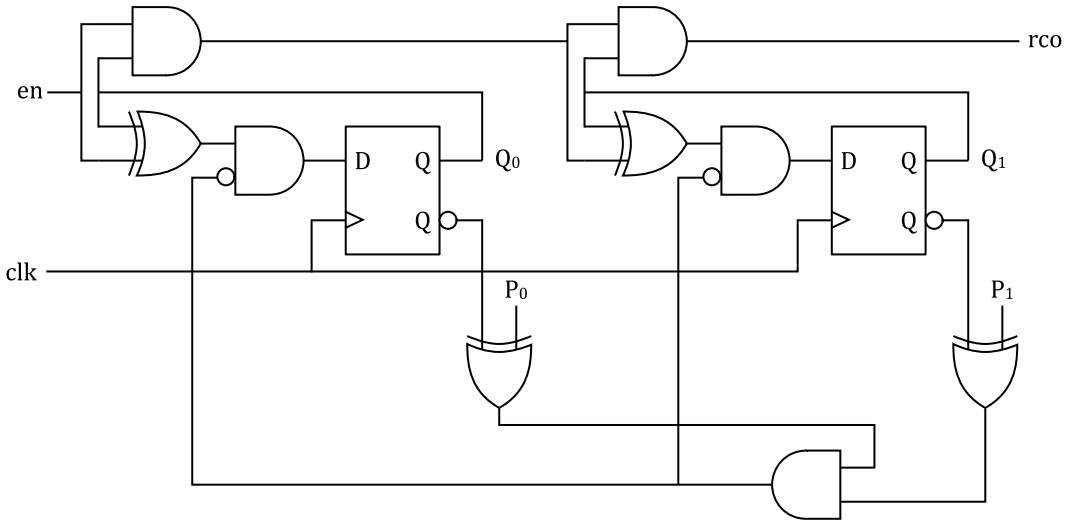
3.3 up-down counter

Create a 4-bit up-down counter using D flip-flops and NAND gates.
The up-down counter has a control input up $\overline{\text{down}}$. If up $\overline{\text{down}}$ =**`'1'`**, the circuit counts upwards. If up $\overline{\text{down}}$ =**`'0'`**, the circuit counts down.

cnt/cnt-iterative-03

3.4 Programmable Counter

The following figure shows the schematic of a programmable counter.



Determine the length of the counting sequence as a function of the input number $[P_1, P_0]$.
Modify this circuit to make the zero setting cascadable.

cnt/cnt-iterativ-04