Digital Design and Computer Organization

Counters - 2

Reetinder Sidhu

Department of Computer Science and Engineering

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Course Outline

- Digital Design
  - Combinational logic design
  - Sequential logic design
    - ★ **Counters - 2**
- Computer Organization
  - Architecture (microprocessor instruction set)
  - Microarchitecure (microprocessor operation)

Concepts covered

- Arbitrary Modulus Counters

What is the Modulus of a Counter?

Counter Modulus

- The number of states a counter sequences through before repeating is the **modulus** of the counter
  - An n-bit counter counting from 0 to $2^n - 1$ has a modulus of 2^n
- A counter of modulus k is also called a modulo k or mod k counter
- Counters studied so far have a modulus of 2^n
- How to construct counters whose modulus is not 2^n?

Arbitrary Modulus Counter

- Suppose we want a modulus k incrementing counter that counts from 0 to $k - 1$
- Select value n such that $2^{n-1} < k < 2^n$
- Start with an n-bit (modulus 2^n) incrementing counter
- Two things are required:
  - Ability to detect when the count value has reached $k - 1$
  - Ability to reset the count value to 0 when above happens

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Arbitrary Modulus Counter

- Counter value can be reset to 0 if D flip-flops with reset are used
- An AND gate can be used to detect when the count value becomes $k - 1$
  - Some inputs may need to be inverted

Modulus 5 Incrementing Counter

- Count sequence: 000, 001, 010, 011, 100, 000, 001, ...

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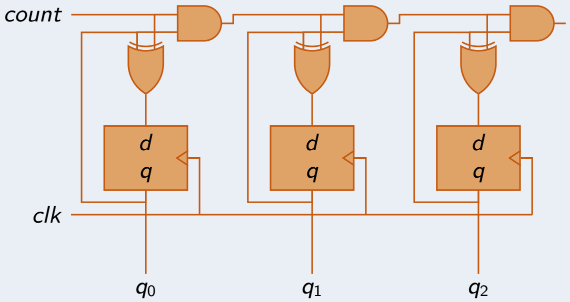
Modulus 5 Incrementing Counter

- Count sequence: 000, 001, 010, 011, 100, 000, 001, ...
- Since $2^2 < 5 < 2^3$, we start with a 3-bit incrementing counter



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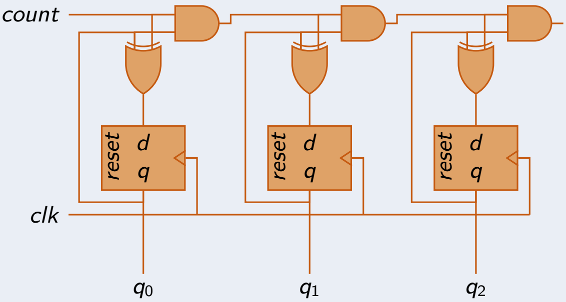

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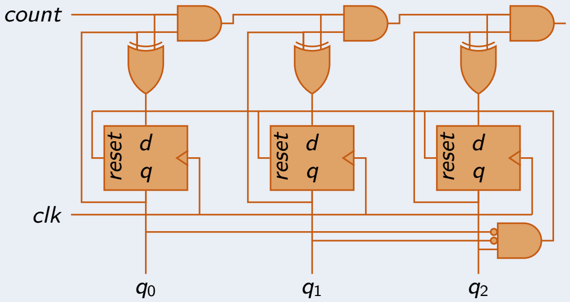
- D flip-flops with reset are used
- AND gate used to detect count value 100 ($k - 1$)



Resettable Flip-Flop

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Flip-flop with additional **reset** signal used to store 0 irrespective of the input

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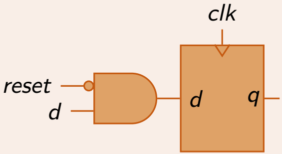
- Logic Diagram:



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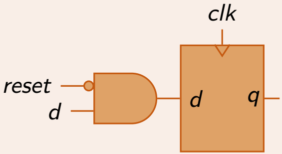
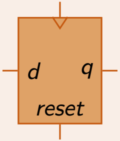


- Symbol:



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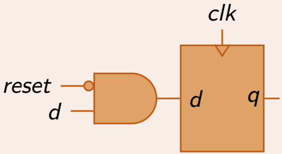

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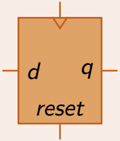

- At the rising edge of *clk*:

reset	*d*	*q*
0	0	0
0	1	1
1	0	0
1	1	0

COUNTERS - 2

Settable Flip-Flop

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Flip-flop with additional **set** signal used to store 1 irrespective of the input

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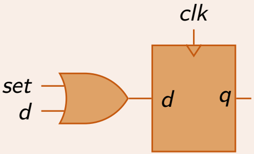

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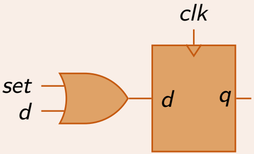

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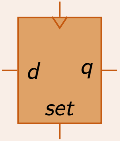

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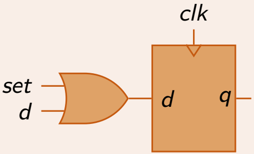

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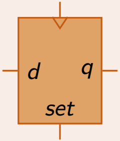

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COUNTERS - 2

Ring Counter

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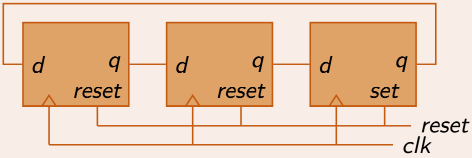
3-bit Ring Counter



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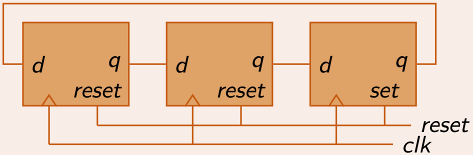
3-bit Ring Counter



- Also called “one-hot” counters (as in one-hot encoding)

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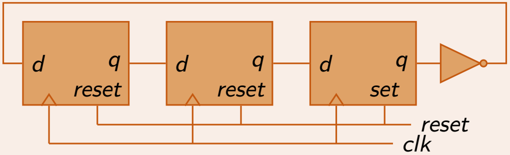
Think About It

3-bit Johnson (Twisted Ring) Counter



- What is the modulus of an *n*-bit Johnson counter?