Datapath Functional Units

Contents

- Comparator

- Funnel Shifter

- Multi Input Adder
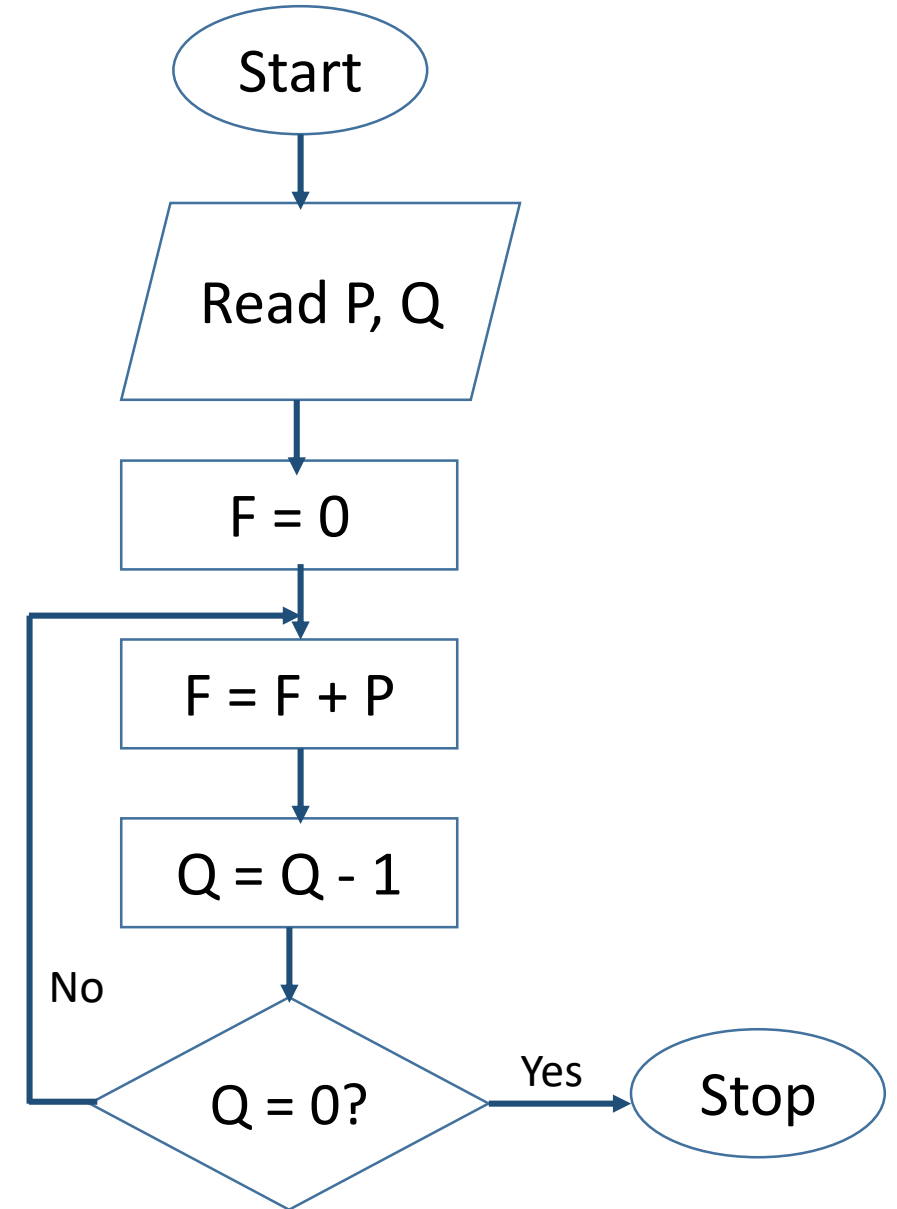
- Multiplier

- Divider

Introduction

- Data path
  - Consists of functional units where all computations are carried out
    - Ex: Registers, multiplexers, bus, adders, multipliers, counter
- Control path
  - Consists of FSM and provide control signals to the data path in proper sequence
  - With the help of control signals various operations are carried out by the data path
  - Also takes inputs from the data path regarding status information

Introduction

- Illustrate data and control path

  - P = Q + R

  - S = P - R

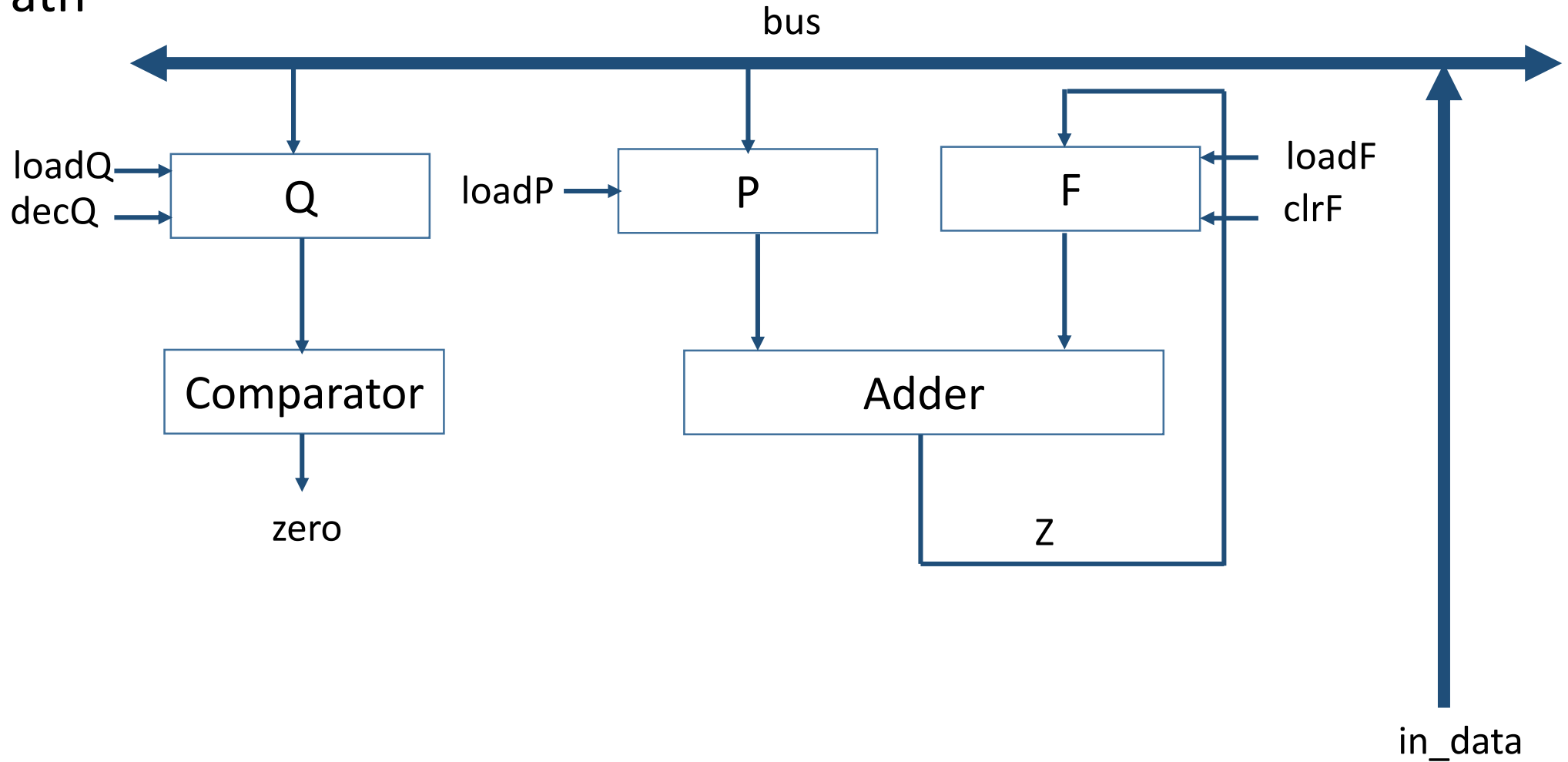# Multiplication by repeated addition

- Illustrate P * Q by repeated addition

- Assumption, Q is not zero

- Identify the functional blocks

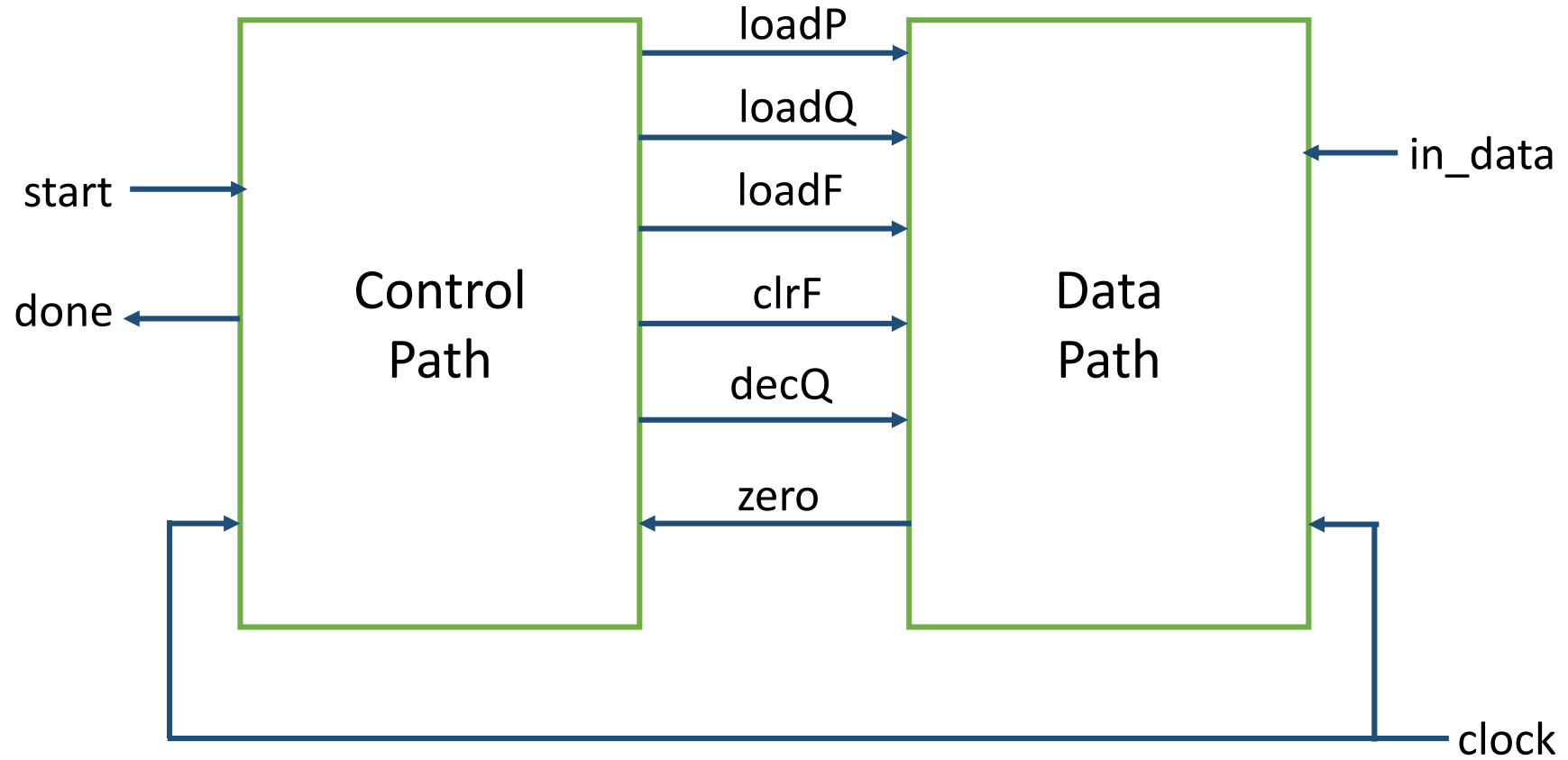- Design the FSM to implement the algorithm with the help of data path

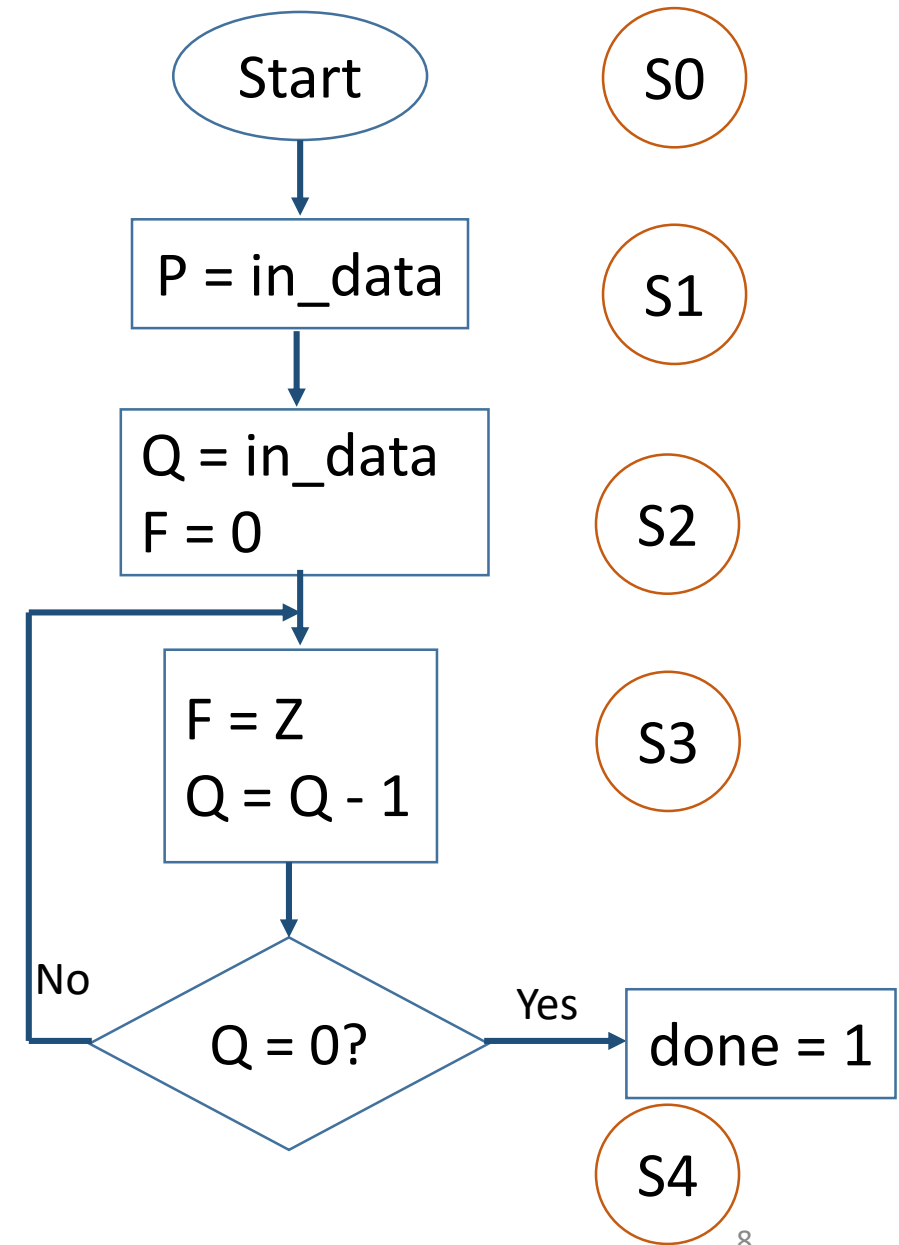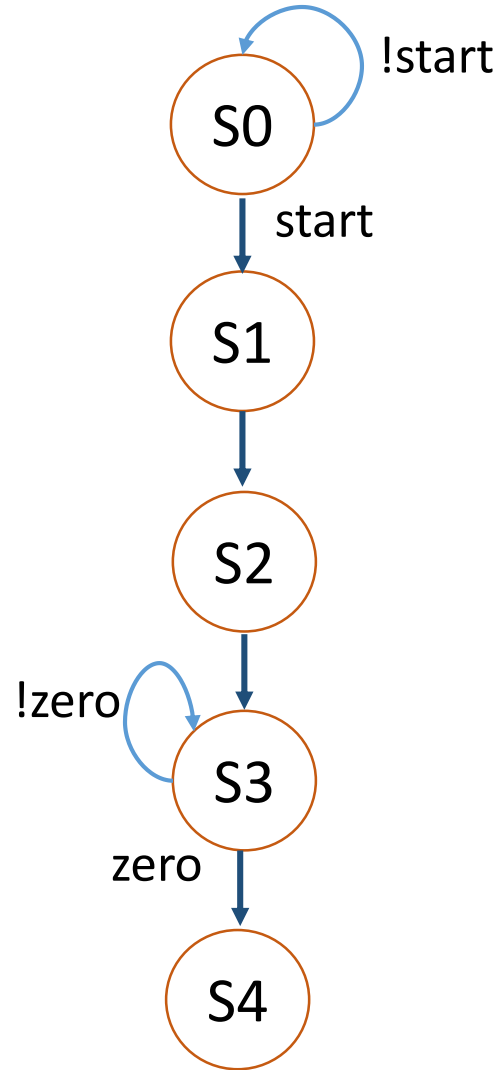# Multiplication by repeated addition

- Data Path

Multiplication by repeated addition

- Block Diagram

Multiplication by repeated addition

- Control Path

State diagram:
- S0 with self-loop !start, transition on start to S1
- S1 to S2
- S2 to S3
- S3 with self-loop !zero, transition on zero to S4

Flowchart:
- Start
- P = in_data (S1)
- Q = in_data, F = 0 (S2)
- F = Z, Q = Q - 1 (S3)
- Q = 0? — No loops back, Yes → done = 1 (S4)

States: S0, S1, S2, S3, S4

Multiplication by repeated addition

- Write HDLs and simulate
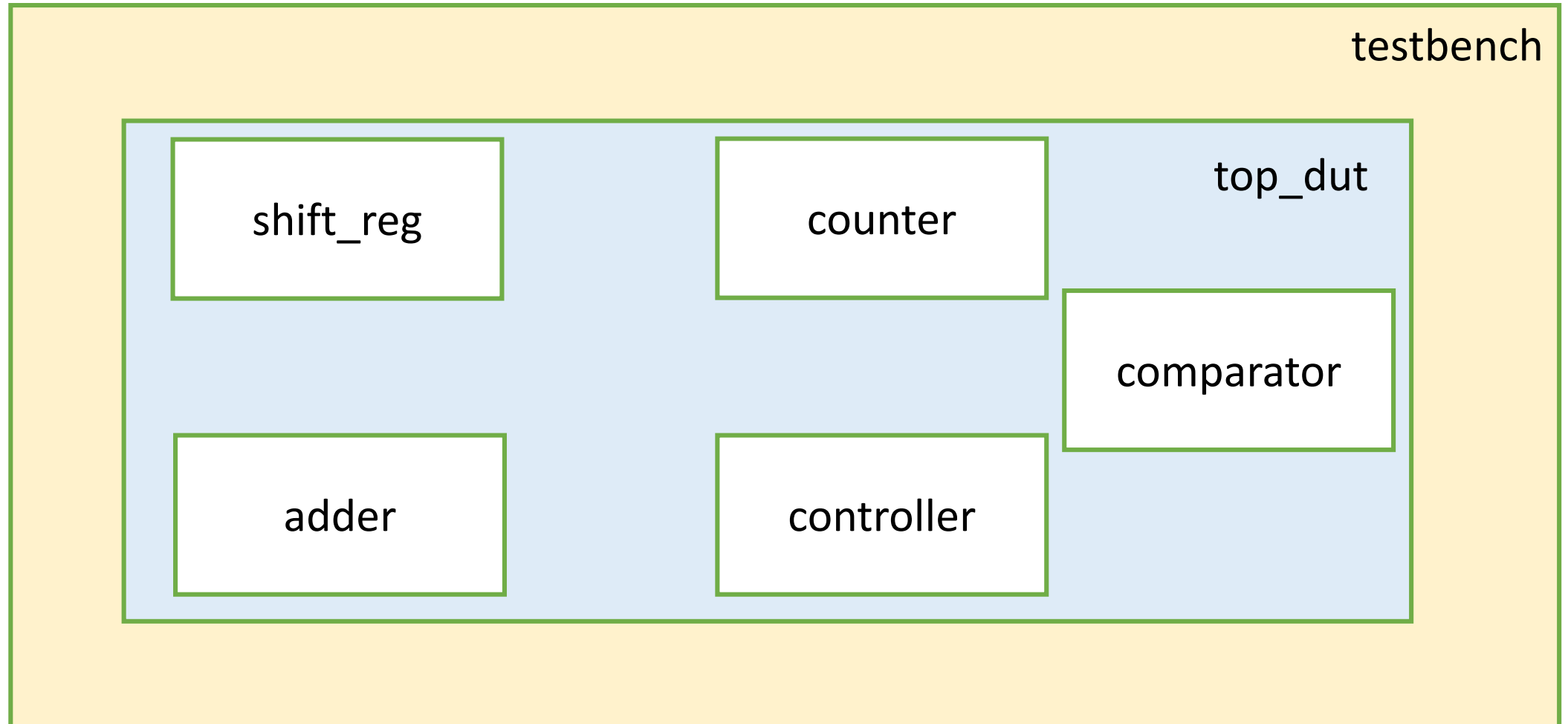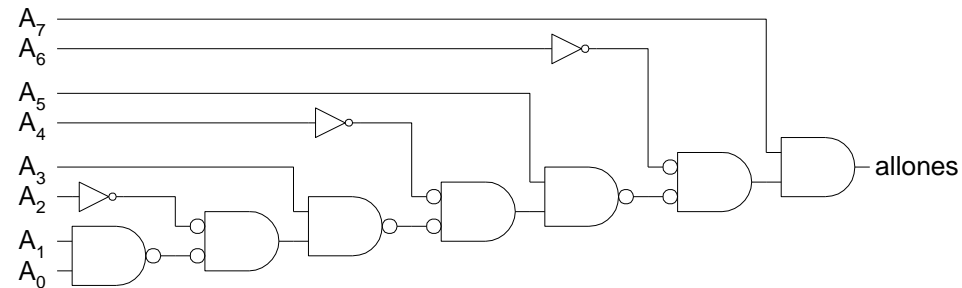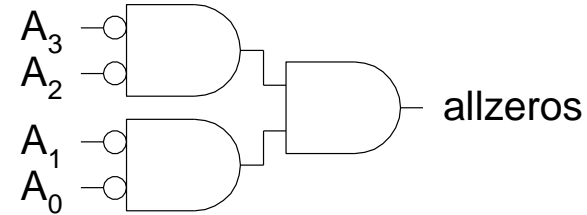
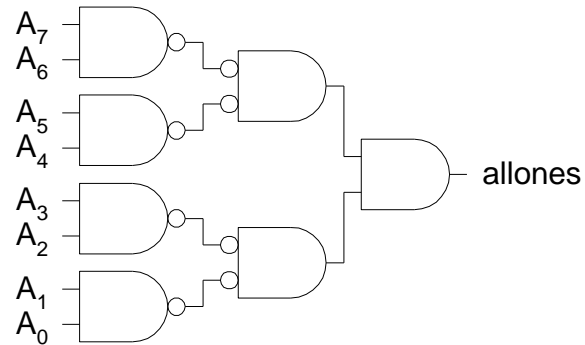# Comparators

- 0's detector: $A = 00...000$

- 1's detector: $A = 11...111$

- Equality comparator: $A = B$
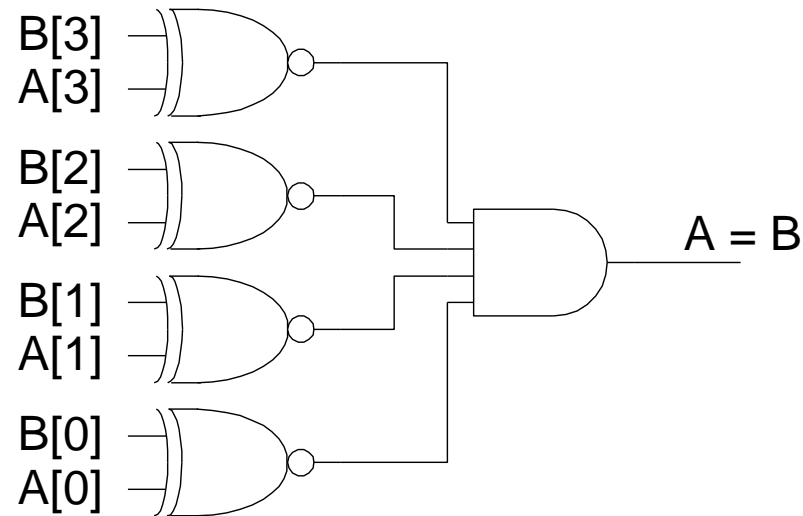
- Magnitude comparator: $A < B$

1's & 0's Detectors

- 1's detector: N-input AND gate
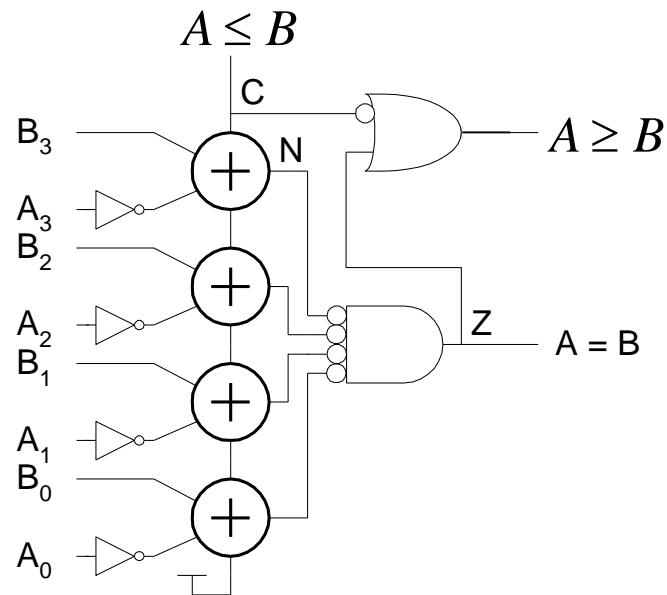- 0's detector: NOTs + 1's detector (N-input NOR)

Equality Comparator

- Check if each bit is equal (XNOR, an equality detector gate)

- 1's detect on bitwise equality

Magnitude Comparator

- Compute B-A and look at sign
- B-A = B + ~A + 1
- For unsigned numbers, carry out is sign bit

Signed vs. Unsigned

- For signed numbers, comparison is harder
    - C: carry out
    - Z: zero (all bits of A-B are 0)
    - N: negative (MSB of result)
    - V: overflow (inputs had different signs, output sign $\neq$ B)

Considering B - A

Relation	Unsigned Comparison	Signed Comparison
$A = B$	Z	Z
$A \neq B$	$\overline{Z}$	$\overline{Z}$
$A < B$	$C \cdot \overline{Z}$	$\overline{S} \cdot \overline{Z}$
$A > B$	C	S
$A \leq B$	C	$\overline{S}$
$A \geq B$	$\overline{C} + Z$	$S + Z$

Datapath

Shifters

- Logical Shift:
  - Shifts number left or right and fills with 0's
    - 1011 LSR 1 = 0101   1011 LSL1 = 0110

- Arithmetic Shift:
  - Shifts number left or right. Rt shift sign extends
    - 1011 ASR1 = 1101   1011 ASL1 = 0110

- Rotate:
  - Shifts number left or right and fills with lost bits
    - 1011 ROR1 = 1101   1011 ROL1 = 0111

Funnel Shifter

- A funnel shifter creates a 2N – 1-bit input word Z from A then selects an *N*-bit field from this input word

- Selects N-bit field Y from 2N-bit input
  - Shift by k bits ($0 \leq k < N$)
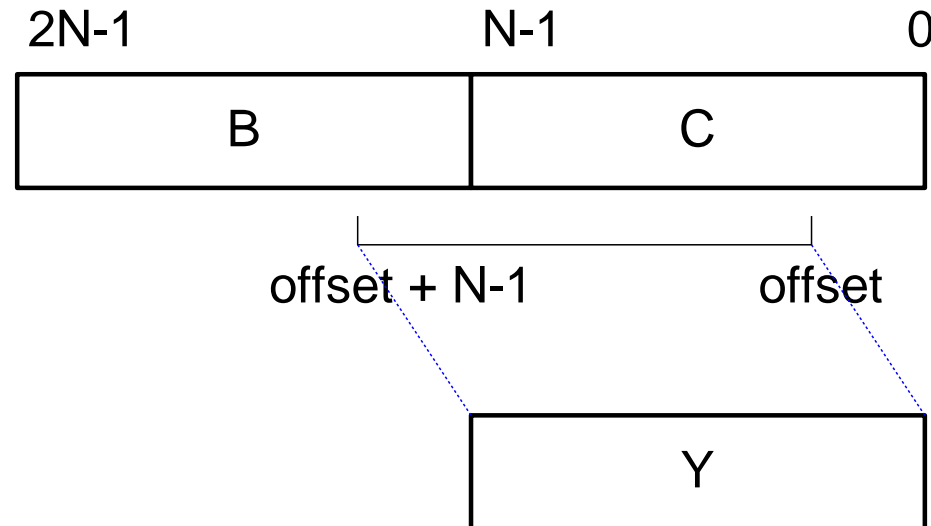
Funnel Shifter Design

- Log N stages of 2-input muxes