3.4 Sequential logic

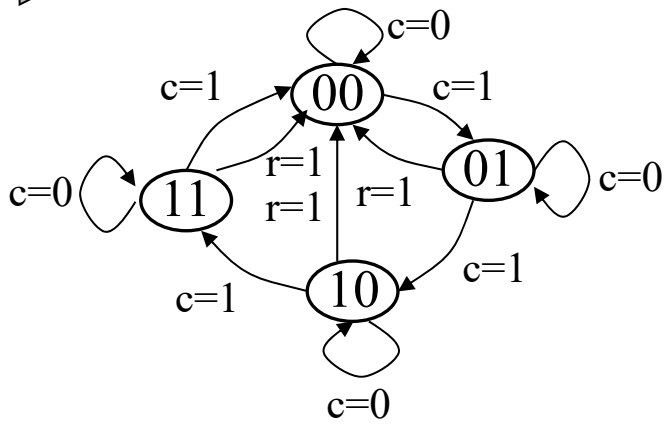
Fundamentals of control circuits

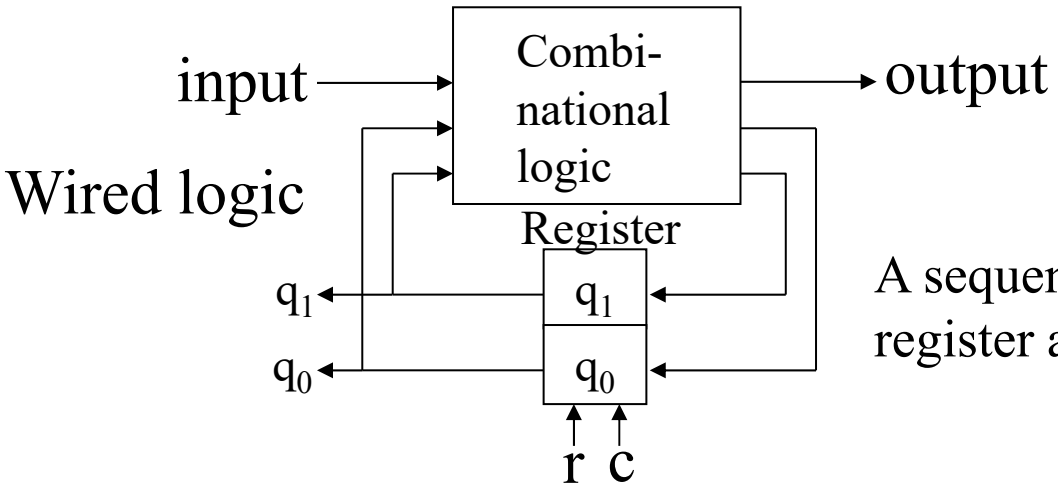
Implementation of sequential logic

Characteristic table

r	c	q_1q_0 (n + 1)
0	0	q_1q_0 (n)
0	1	q_1q_0 (n) + "01"
1	0	0 0
1	1	0 0

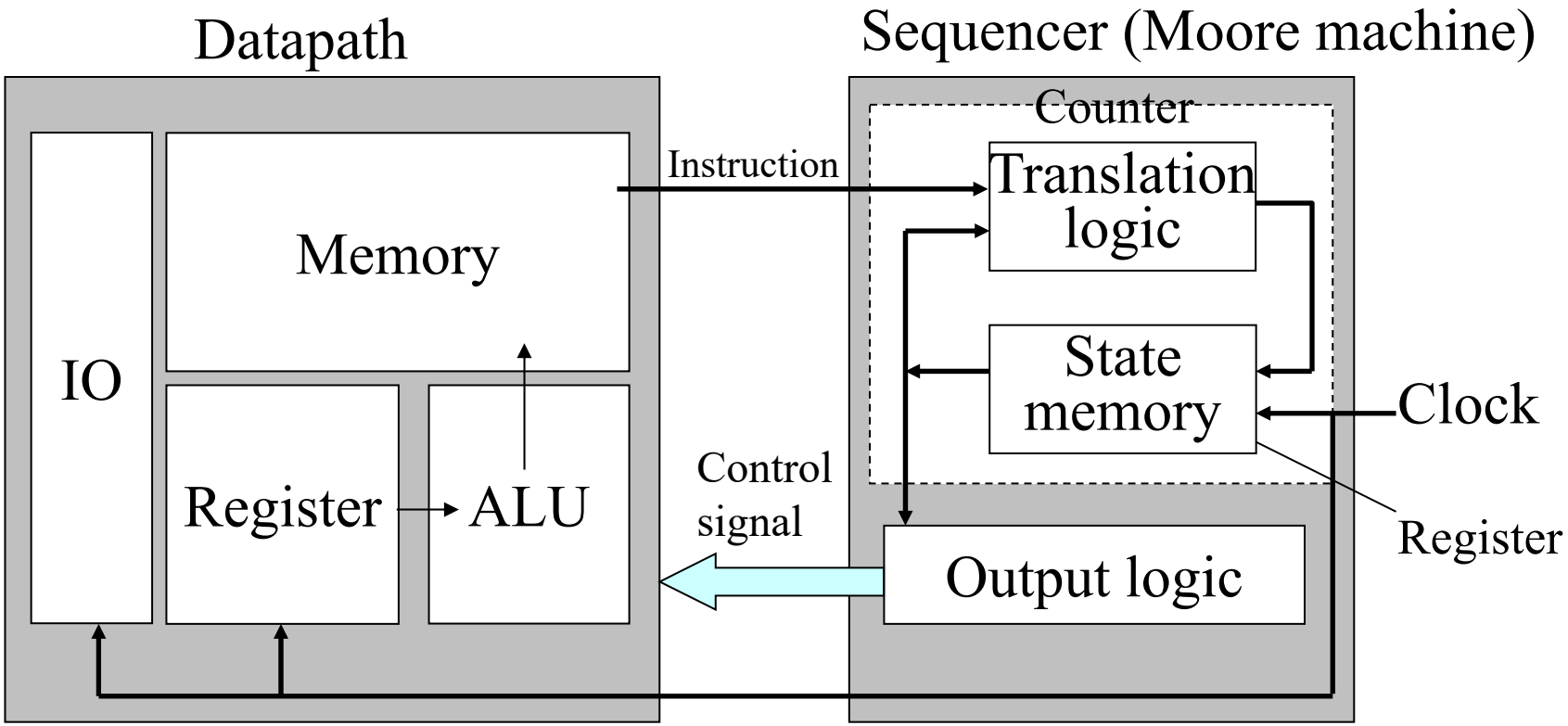
State Transition Diagram





A sequential logic consists of a register and a combinational logic.

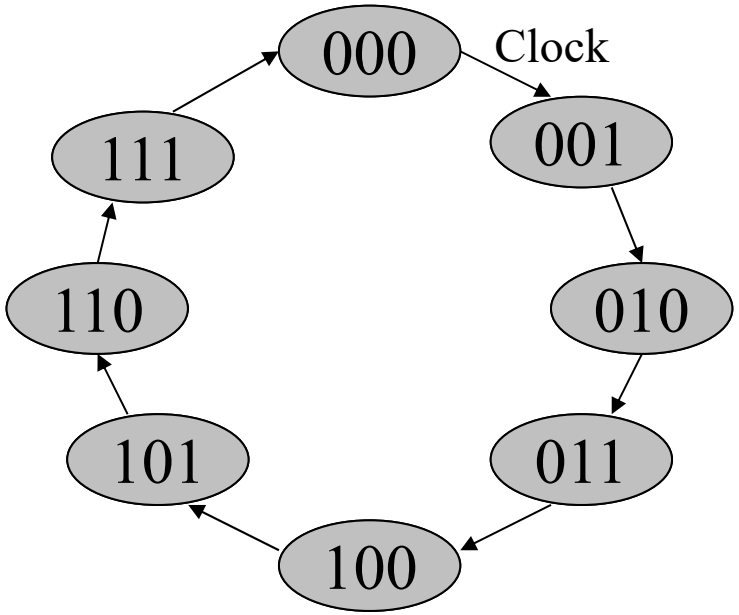
Datapath and sequencer



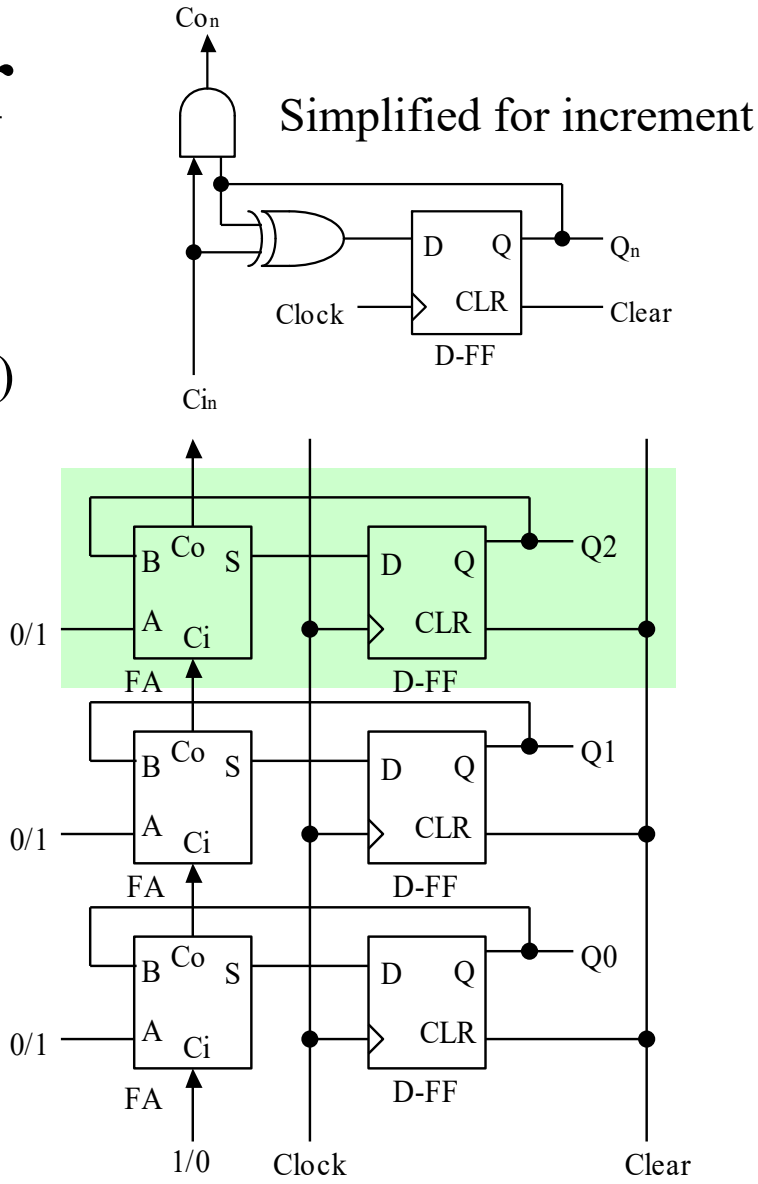
Synchronous state machine

Binary counter

A	Ci	
0	1	→ (Increment)
1	0	→ (Decrement)



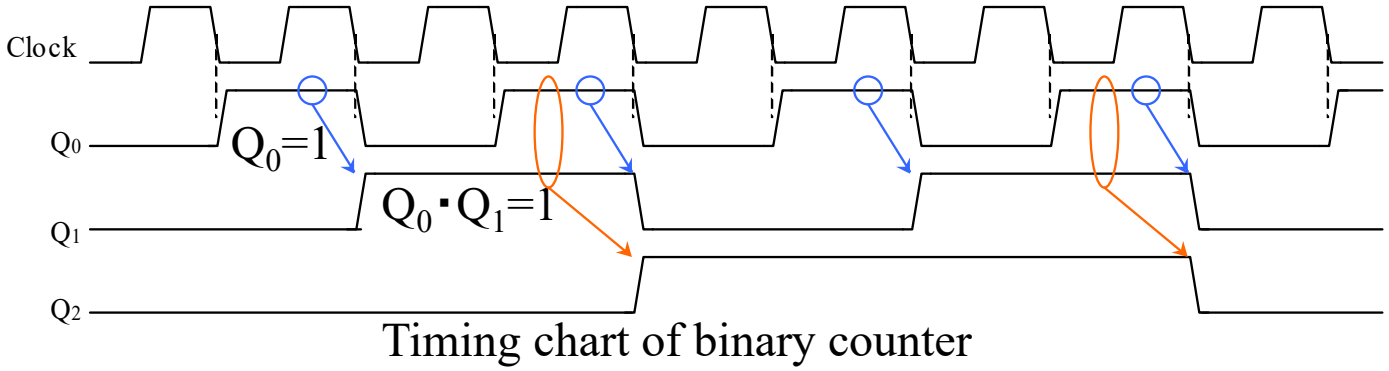
State transition of binary counter



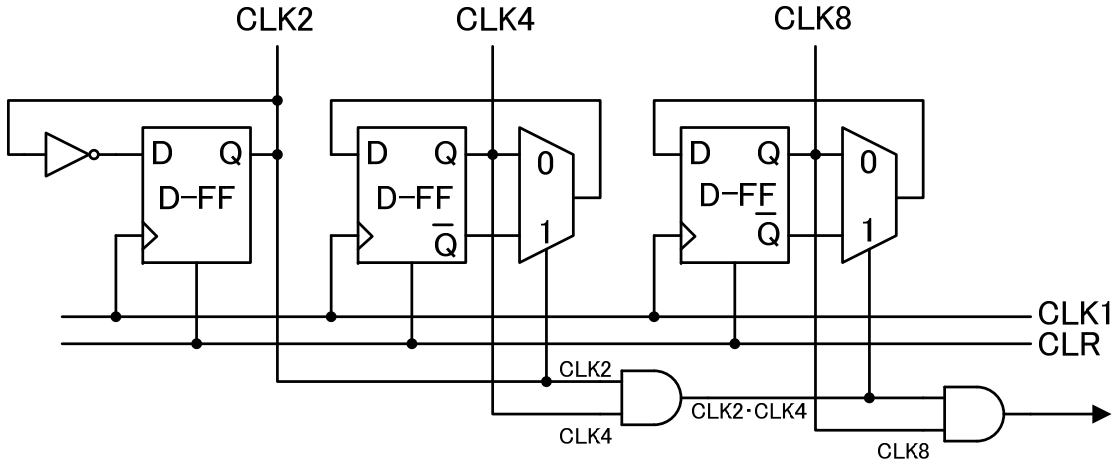
Ripple carry counter

Binary counter with carry lookahead mechanism

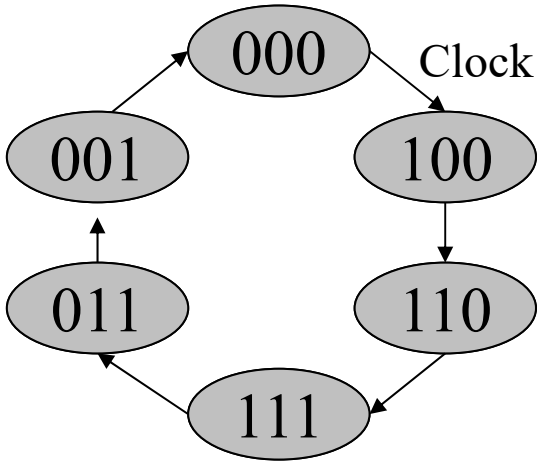
A value of D_1 is determined according to the result of $Q_0 \cdot Q_1$ (In general, $\prod_{i=0}^{n-1} Q_i$).
The maximum clock frequency is higher than that of the ripple carry counter.

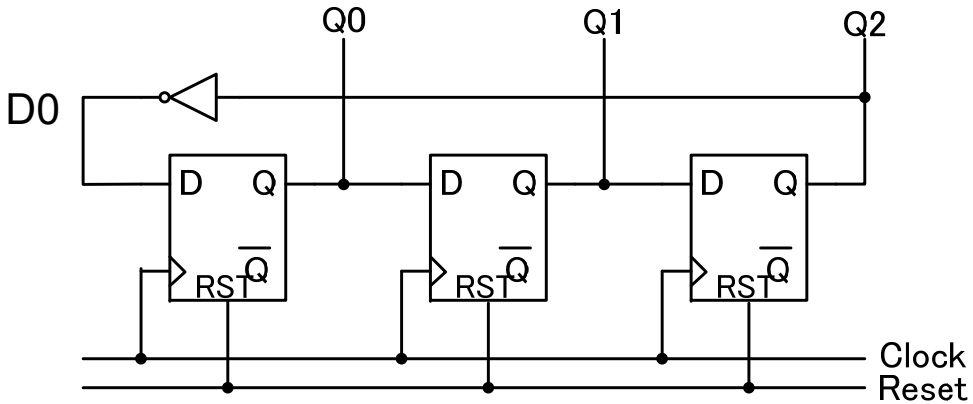


Timing chart of binary counter



Johnson counter





	Q0	Q1	Q2	D0
	0	0	0	1
	1	0	0	1
	1	1	0	1
	1	1	1	0
	0	1	1	0
	0	0	1	0
	0	0	0	1

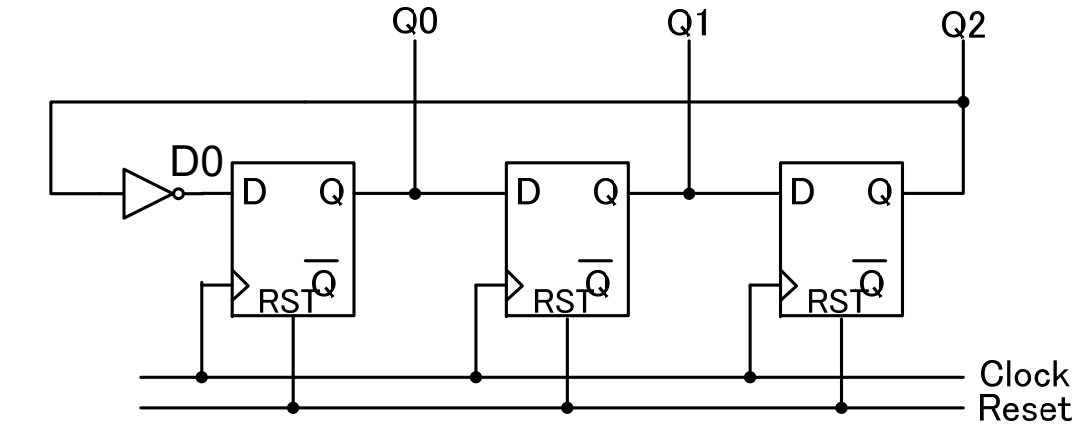
Clock

NOT

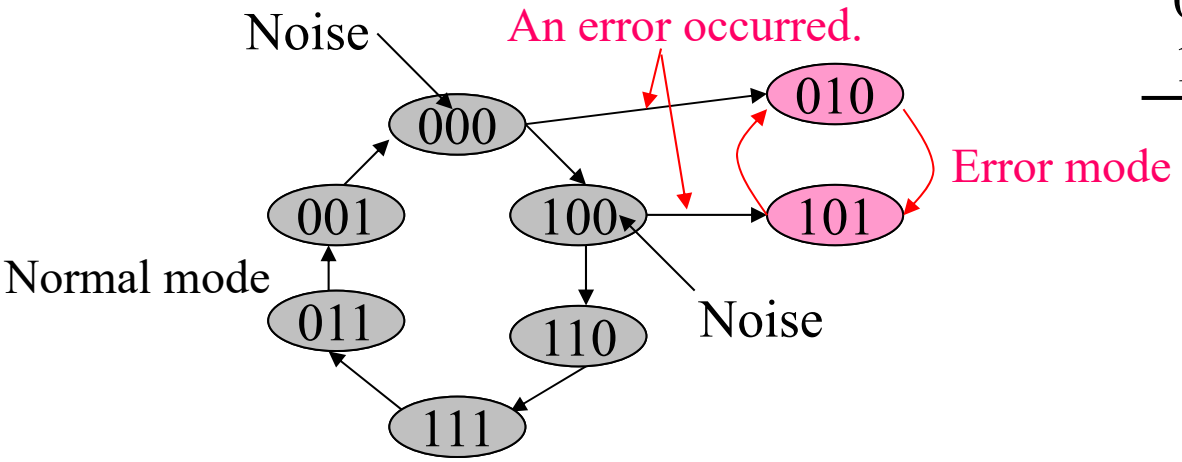
State transition of Johnson counter

There is no hazard during the state transition, because the 1-bit of the state variable is inverted for every transition.

Transition to undefined state



Q0	Q1	Q2	D0
0	0	0	1
1	0	0	1
1	1	0	1
1	1	1	0
0	1	1	0
0	0	1	0
0	1	0	Undefined
1	0	1	Undefined

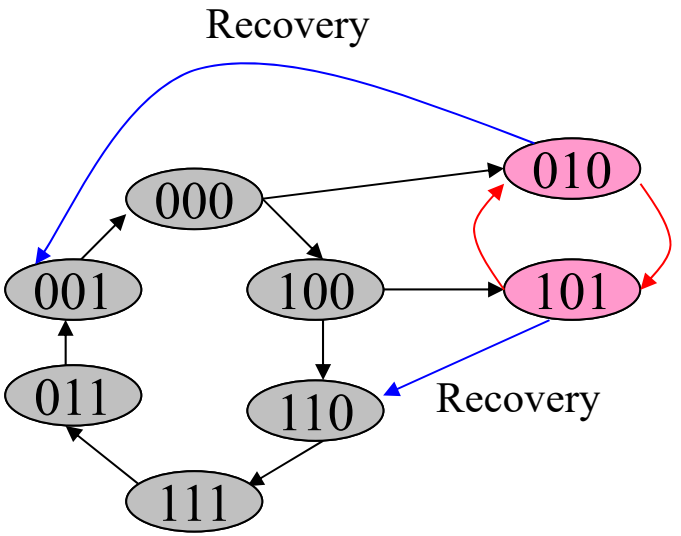


Recovery by error handling

Q0	Q1	Q2	D0	
0	0	0	1	Normal mode
1	0	0	1	
1	1	0	1	
1	1	1	0	
0	1	1	0	
0	0	1	0	
0	1	0	0	Error mode
1	0	1	1	

Recovery

Recovery



Note: A condition branching that has an undefined transition may cause an unexpected error in the hardware and software design.

Design example of error handling

Truth table of translation logic

Q0	Q1	Q2	D0
0	0	0	1
1	0	0	1
1	1	0	1
1	1	1	0
0	1	1	0
0	0	1	0
0	1	0	0
1	0	1	1

NOT

Q2

Error detection

$$E = Q_0 \cdot \overline{Q_1} \cdot Q_2 + \overline{Q_0} \cdot Q_1 \cdot \overline{Q_2} = \overline{\overline{Q_0 \cdot \overline{Q_1} \cdot Q_2} \cdot \overline{\overline{Q_0} \cdot Q_1 \cdot \overline{Q_2}}}$$

Next state of D-FF_0

$$D0 = E \cdot Q_2 + \overline{E} \cdot \overline{Q_2} = \overline{E \oplus Q_2}$$