

Computer Science 210 s1c
Computer Systems 1
2008 Semester 1
Lecture Notes

Lecture 9, 26Mar08:

Finite State Machines & the von Neumann Computer

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Credits: Slides prepared by Gregory T. Byrd, North Carolina State University

Announcement

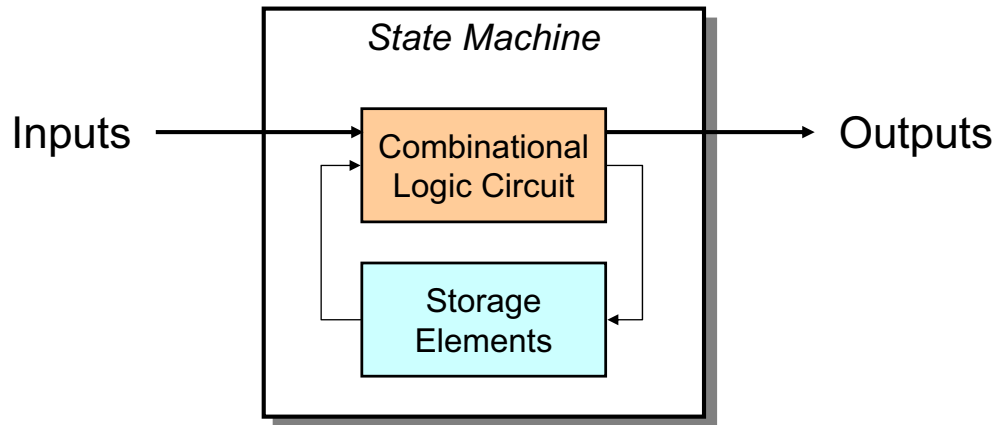
CS210 Test date

- In-class
- Thursday, 24Apr08
- Location: to be announced

State Machine

Another type of sequential circuit

- Combines combinational logic with storage
- “Remembers” state, and changes output (and state) based on **inputs** and **current state**



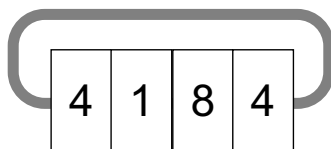
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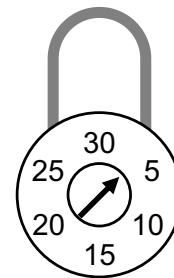
Combinational vs. Sequential

Two types of “combination” locks



Combinational

Success depends only on the **values**, not the order in which they are set.



Sequential

Success depends on the **sequence** of values (e.g, R-13, L-22, R-3).

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State

The **state** of a system is a **snapshot** of **all the relevant elements** of the system at the moment the snapshot is taken.

Examples:

- The state of a tic-tac-toe (Noughts & Crosses) game can be represented by the placement of X's and O's on the board.
- The state of a basketball game can be represented by the scoreboard.
 - Number of points, time remaining, possession, etc.

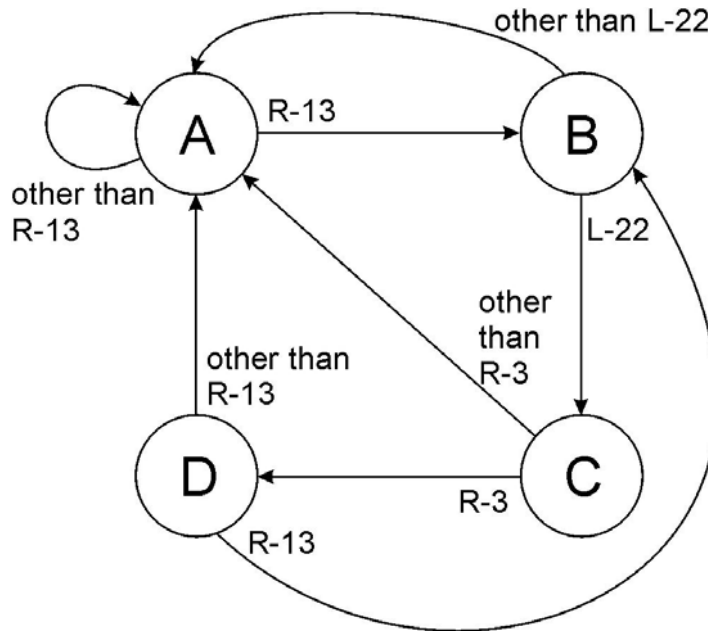
State of Sequential Lock

Our lock example has four different states, labelled A-D:

- A:** The lock is **not open**,
and no relevant operations have been performed.
- B:** The lock is **not open**,
and the user has completed the **R-13** operation.
- C:** The lock is **not open**,
and the user has completed **R-13**, followed by **L-22**.
- D:** The lock is **open**.

State Diagram

Shows **states** and **actions** that cause a **transition** between states.



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Finite State Machine

A description of a system with the following components:

1. A finite number of **states**
2. A finite number of external **inputs**
3. A finite number of external **outputs**
4. An explicit specification of all **state transitions**
5. An explicit specification of what determines each external **output value**

Often described by a state diagram.

- Inputs trigger state transitions.
- Outputs are associated with each state (or with each transition).

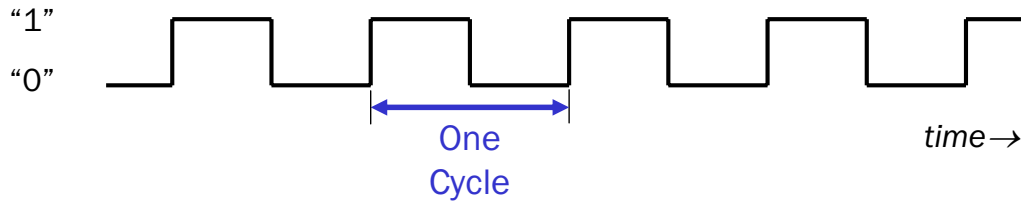
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The Clock

Frequently, a **clock circuit** triggers transition from one state to the next.



At the beginning of each clock cycle, state machine makes a transition, based on the current state and the external inputs.

- **Not always required. In lock example, the input itself triggers a transition.**

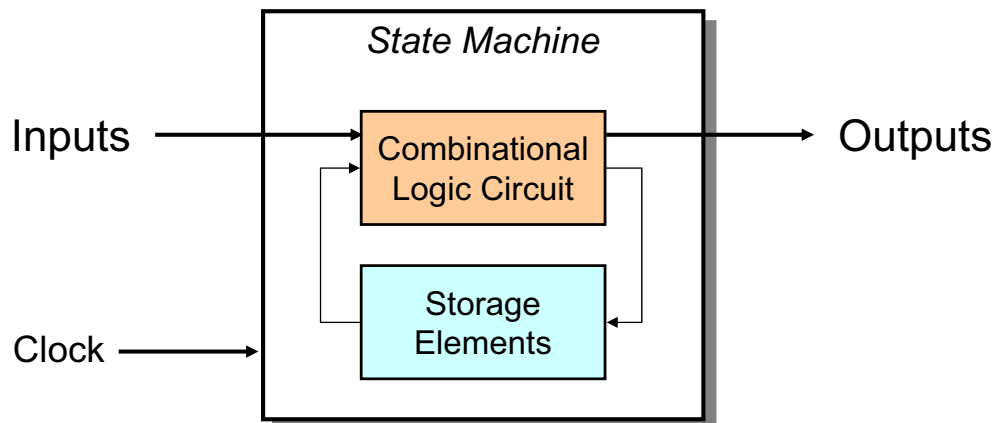
Implementing a Finite State Machine

Combinational logic

- Determine outputs and next state.

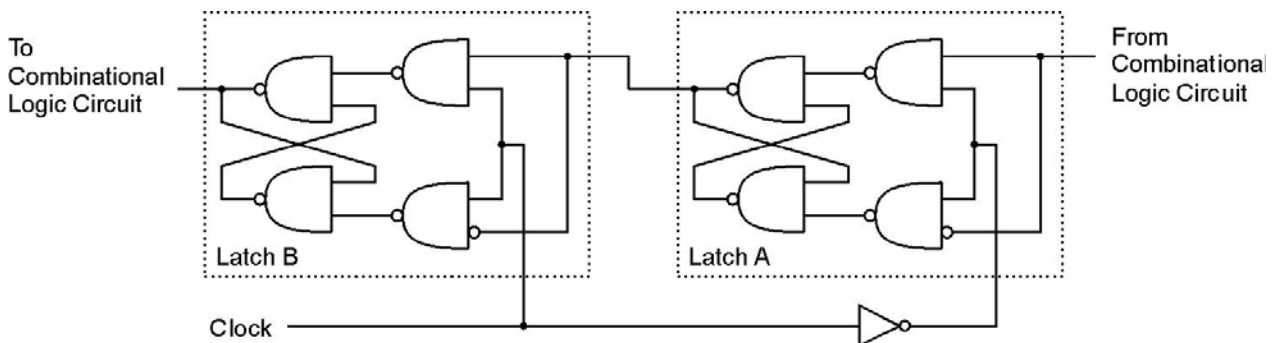
Storage elements

- Maintain state representation.



Storage: Master-Slave Flipflop

A pair of gated D-latches,
to isolate *next* state from *current* state.



During 1st phase (clock=1), previously-computed state becomes *current* state and is sent to the logic circuit.

During 2nd phase (clock=0), *next* state, computed by logic circuit, is stored in Latch A.

Storage

Each master-slave flipflop stores one state bit.

The number of storage elements (flipflops) needed is determined by the number of states (and the representation of each state).

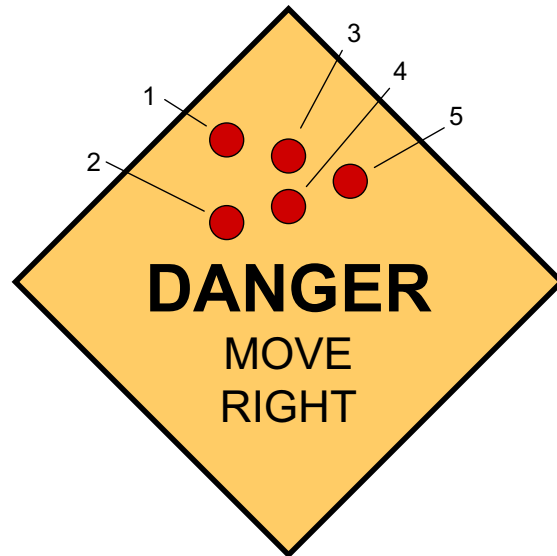
Examples:

- Sequential lock
 - Four states – two bits
- Basketball scoreboard
 - 7 bits for each score, 5 bits for minutes, 6 bits for seconds, 1 bit for possession arrow, 1 bit for half, ...

Complete Example

A blinking traffic sign

- No lights on
- 1 & 2 on
- 1, 2, 3, & 4 on
- 1, 2, 3, 4, & 5 on
- (repeat as long as switch is turned on)

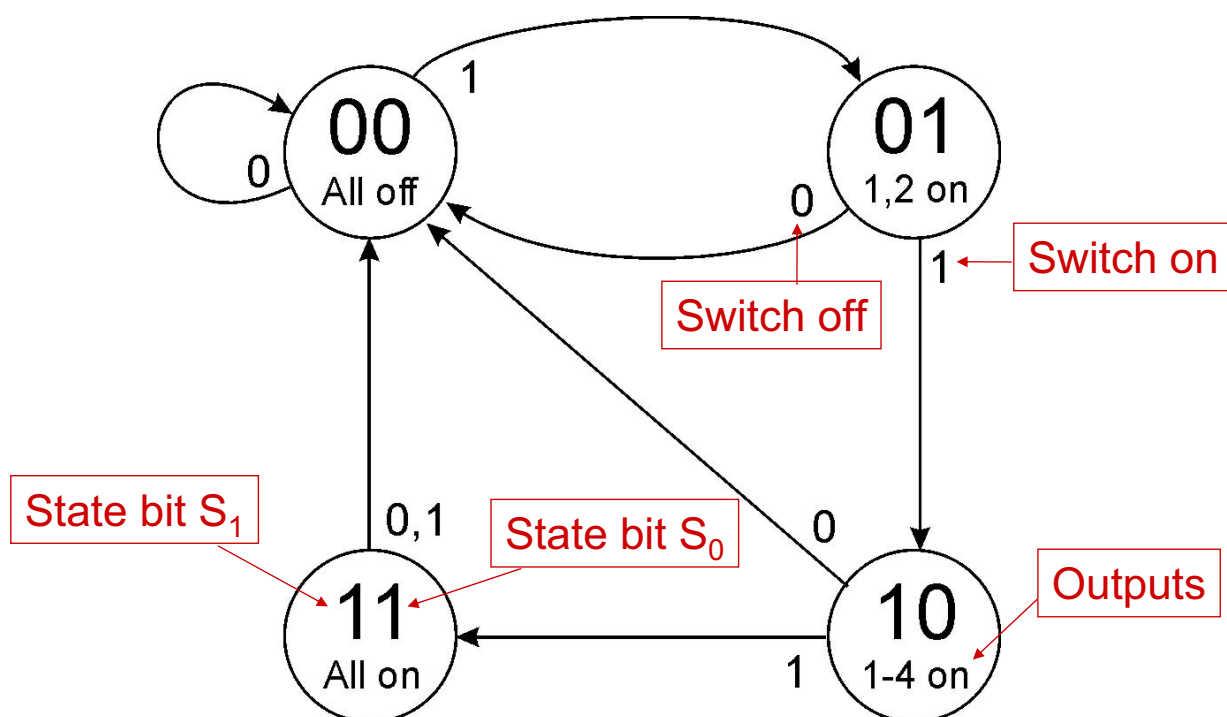


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Traffic Sign State Diagram



Transition on each clock cycle.

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Traffic Sign Truth Tables

Outputs
(depend only on state: S_1S_0)

S_1	S_0	Z	Y	X
0	0	0	0	0
0	1	1	0	0
1	0	1	1	0
1	1	1	1	1

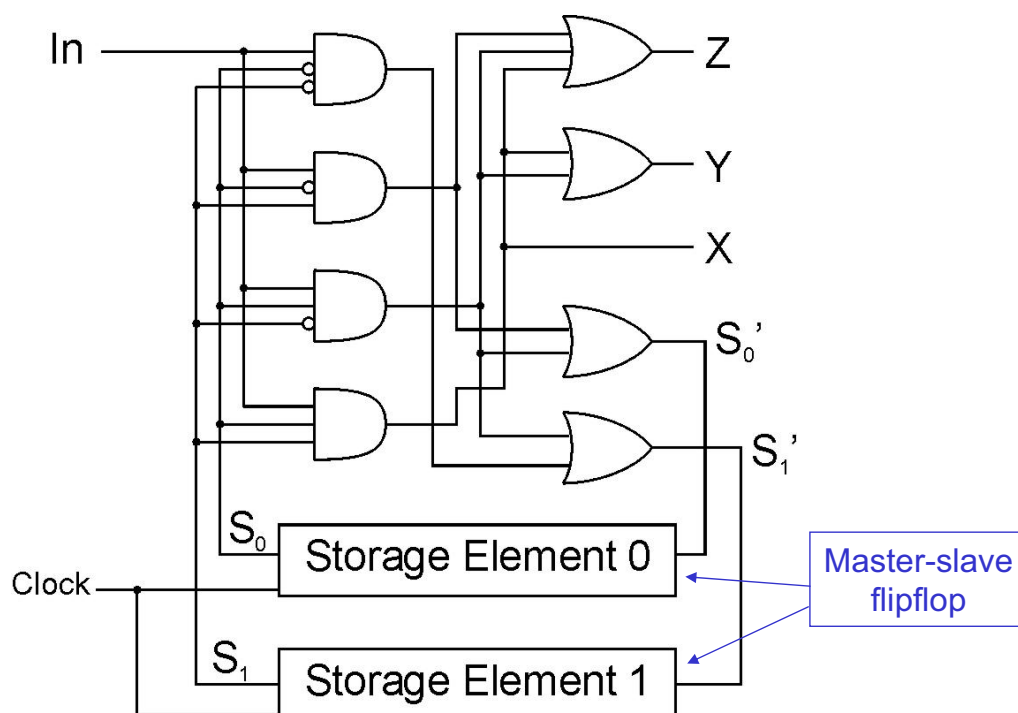
Lights 1 and 2
Lights 3 and 4
Light 5

Next State: $S_1'S_0'$
(depend on state and input)

In	S_1	S_0	S_1'	S_0'
0	X	X	0	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	1
1	1	1	0	0

Whenever $In=0$, next state is 00.

Traffic Sign Logic



From Logic to Data Path

The data path of a computer is all the logic used to process information.

- See the data path of the LC-3 on next slide.

Combinational Logic

- Decoders – convert instructions into control signals
- Multiplexers – select inputs and outputs
- ALU (Arithmetic and Logic Unit) – operations on data

Sequential Logic

- State machine – coordinate control signals and data movement
- Registers and latches – storage elements

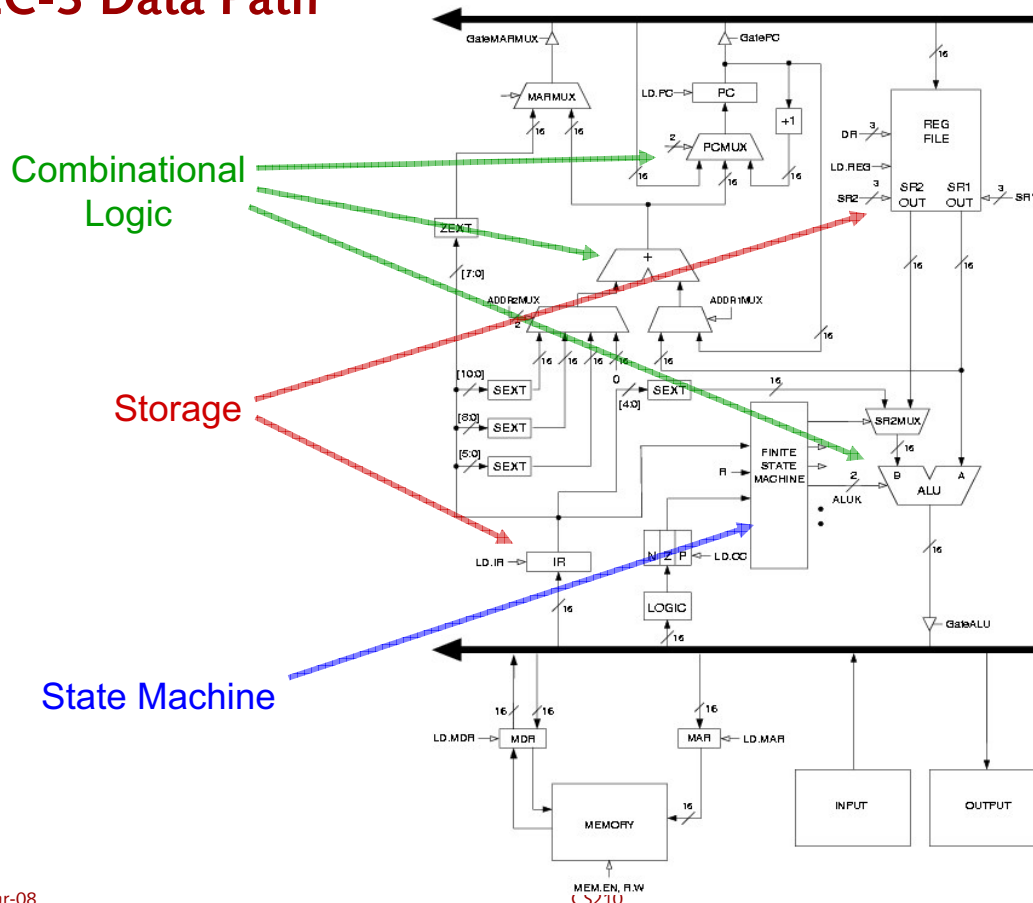
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LC-3 Data Path



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