5.1 State Machine Charts

1 SM Charts

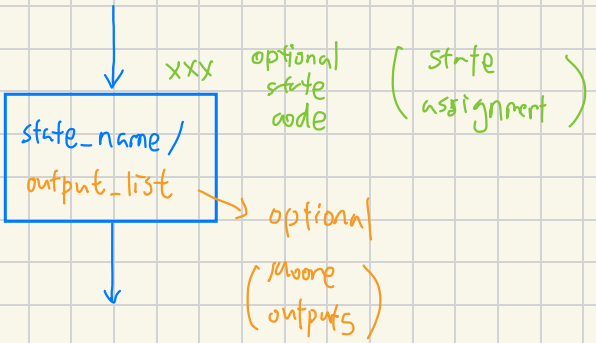
- SM Charts:
  - resemble software flowcharts
  - useful in behavioral-level design entry

- advantages over state graphs:
  - easier to understand
  - conditions of a state graph are automatically fulfilled in an SM chart.
  - directly leads to hardware realization.

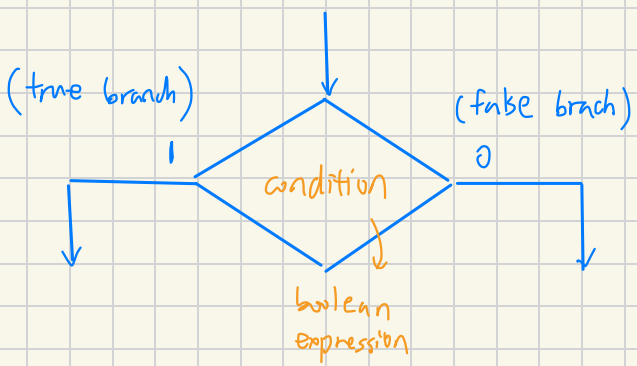
- An SM chart may be converted into different equivalent forms resulting in different implementations

2 Components of SM Charts

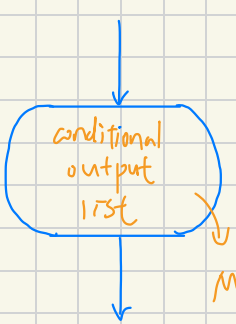
- state box



- decision box



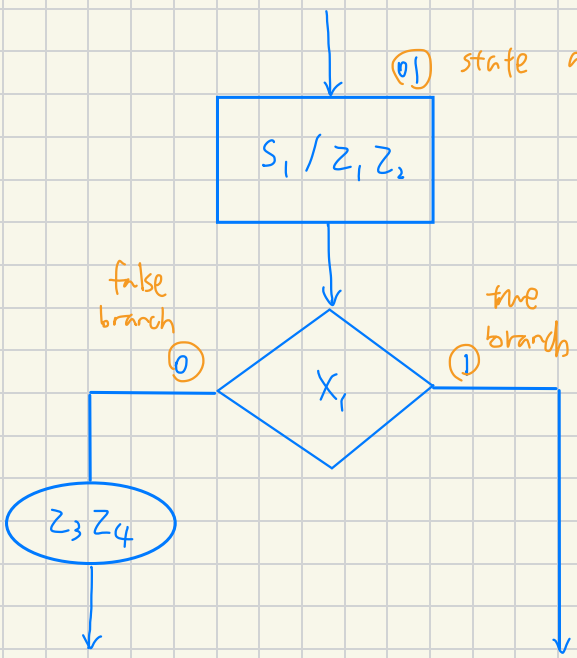
- condition output box



- the conditional outputs depend on both the system and the inputs

- SM box
  - contains exactly one state box, together w/ decision boxes, and conditional output boxes.
  - $\begin{cases} \text{entry path} : 1 \\ \text{exit path} : \geq 1 \end{cases}$
  - Each SM block describes the machine operation during the time the machine is in one state.
  - An SM chart is constructed from SM blocks.

Ex. SM box

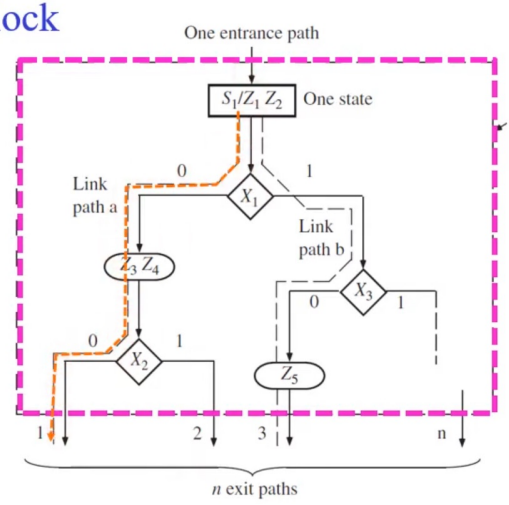


- Z_1, Z_2: Moore outputs
- Z_3, Z_4: Mealy outputs

- link path: a path through an SM block from entrance to exit
  - Each SM block may have one or more link paths.
  - When a digital system enters a state, associated w/ a given SM block, the outputs on the output list
  - The conditions in the decision boxes are evaluated to determine which paths to follow.
  - When a conditional output box is encountered along a path, the corresponding conditional outputs become true.
  - If an output is not encountered along a path, that output is false by default.

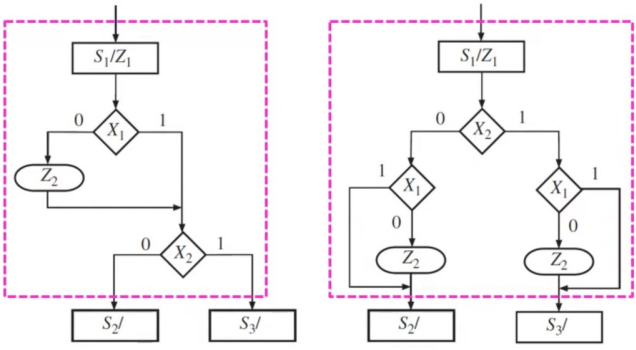
Example

- An SM block w/ 4 link paths:



Example: Equivalent SM Blocks

- Two equivalent SM blocks: for state S_1
  - the output $Z_1 = 1$
  - the output $Z_2 = 1$ if $X_1 = 0$
  - the next state is S_2 if $X_2 = 0$ and S_3 if $X_2 = 1$

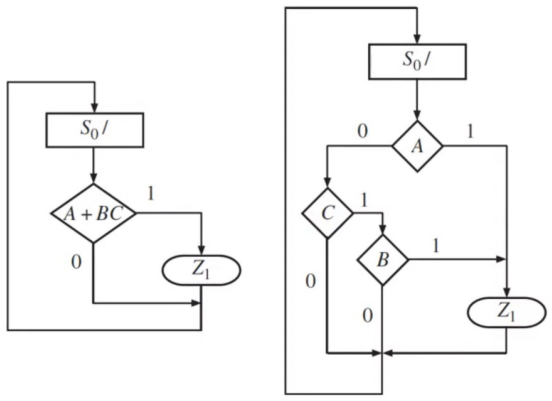


Example: SM Chart for Comb Ckt

- SM charts represent a combinational ckt:

$$Z_1 = A + A'BC = A + BC$$

We don't typically do this, for demonstration purpose only.



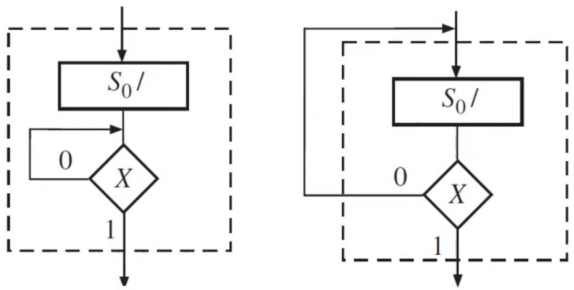
(a) (b)

- Rules for Constructing an SM Block:
  - For every valid combination of input variables, there must be exactly one exit path (next state) defined.
  - No internal feedback within an SM block is allowed.

Examples

Rules for constructing an SM block:

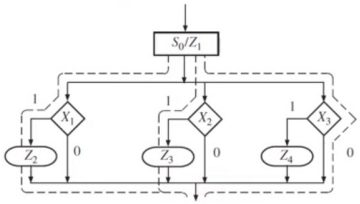
1. Each ***valid combination*** of ***input variables*** leads to **exactly one *exit path*** (a **single *next state***).
2. No **internal feedback** exists within an SM block.

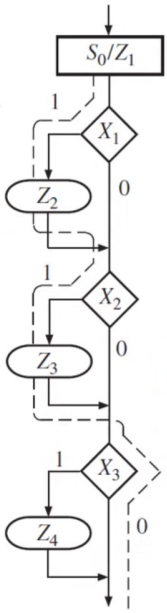


- (a): incorrect ⇐ an SM block w/ feedback
- (b): correct

- Parallel and Serial Forms of SM Blocks
  - parallel form: An SM block can have several parallel paths that lead to the same exit path, and more than one of these paths
  - serial form: only one active link path b/w entrance & exit.

我們希望畫成 serial form
比較不會出錯





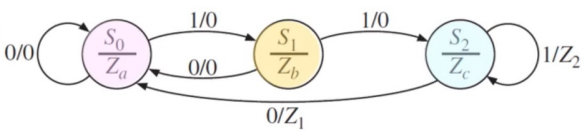
- Serial form: equivalent to the parallel form
  - For any combination of input values, the outputs will be the same as in the equivalent parallel form.

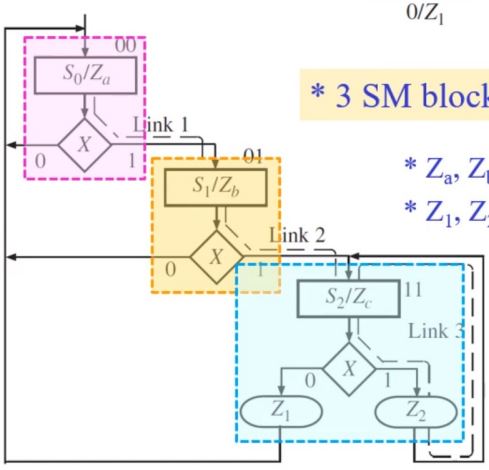
* Regardless of whether the SM block is in serial or parallel form, all the tests take place within **one clock time**.

* Use only the ***serial form*** for SM charts in the remainder of this text.

Conversion of State Graph to SM Chart

- Example:





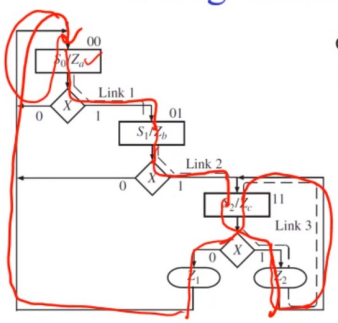
* 3 SM blocks.

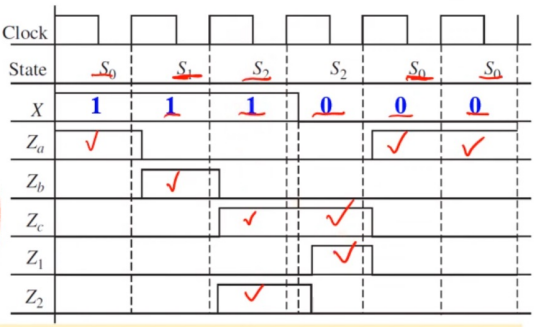
* Z_a, Z_b , Z_c : Moore outputs
* Z_1, Z_2 : Mealy outputs

Timing Chart

- Timing chart of the SM chart:

Input sequence:
X = 1, 1, 1, 0, 0, 0





* The ***Moore outputs*** (Z_a, Z_b, Z_c) depend on the ***state***.
  ⇒ They can change only immediately following a state change.
* The ***Mealy outputs*** (Z_1, Z_2) can change immediately after a ***state*** change or an ***input*** change.