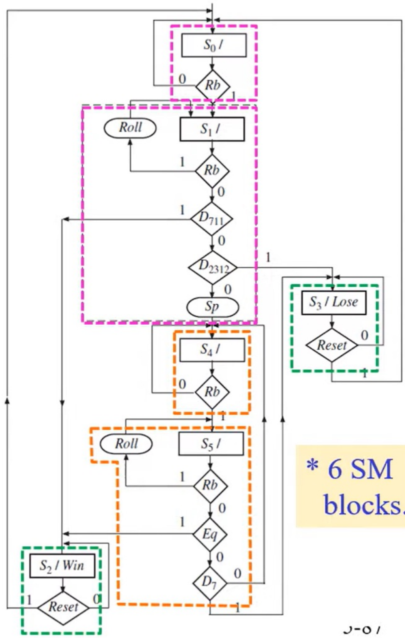
# 5.4 Implementation of Dice Game

## Implementation of the Dice Game

- SM chart for the dice game: (§5-2)
  - Inputs:
    $Rb$, $Reset$, $D_{711}$, $D_7$, $D_{2312}$, $Eq$
  - Outputs:
    $Roll$, $Win$, $Lose$, $Sp$
  - 6 states




* 6 SM blocks.

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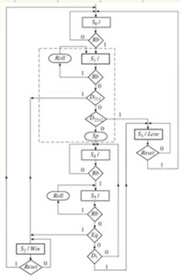
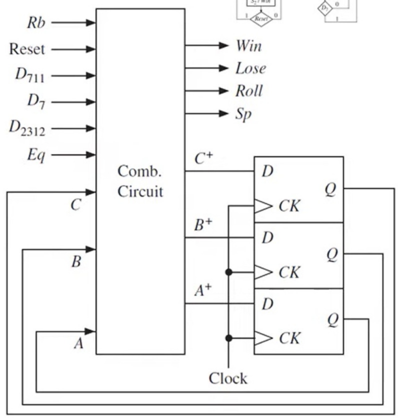
## Block Diagram

- *Hardwired* realization of the SM chart for the dice game :
  - Use comb circuitry and 3 D flip-flops.
  - A straight binary assignment is used:
    - $S_0 = 000$, $S_1 = 001$, ..., $S_5 = 101$.
  - Comb ckt has 9 inputs and 7 outputs.

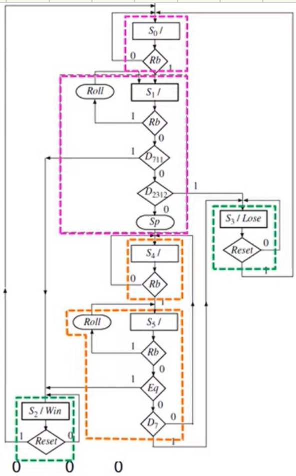
Inputs: 6
$Rb$, $Reset$, $D_{711}$, $D_7$, $D_{2312}$, $Eq$
Outputs: 4
$Roll$, $Win$, $Lose$, $Sp$
States: 6





# State Transition Table

- State transition table:
  - Has one row for each ***link path*** on the SM chart.




| | | Present state | Inputs | | | | | | Next state | | | Out | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ABC | Rb | Reset | $D_7$ | $D_{711}$ | $D_{2312}$ | Eq | $A^+$ | $B^+$ | $C^+$ | Win | | | |
| 1 | $S_0$ | 000 | 0 | — | — | — | — | — | 0 | 0 | 0 | 0 | | | |
| 2 | | 000 | 1 | — | — | — | — | — | 0 | 0 | 1 | 0 | | | |
| 3 | $S_1$ | 001 | 1 | — | — | — | — | — | 0 | 0 | 1 | 0 | | | |
| 4 | | 001 | 0 | — | — | 0 | 0 | — | 1 | 0 | 0 | 0 | | | |
| 5 | | 001 | 0 | — | — | 0 | 1 | — | 0 | 1 | 1 | 0 | | | |
| 6 | | 001 | 0 | — | — | 1 | — | — | 0 | 1 | 0 | 0 | | | |
| 7 | $S_2$ | 010 | — | 0 | — | — | — | — | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 8 | | 010 | — | 1 | — | — | — | — | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 9 | $S_3$ | 011 | — | 1 | — | — | — | — | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 10 | | 011 | — | 0 | — | — | — | — | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 11 | $S_4$ | 100 | 0 | — | — | — | — | — | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | | 100 | 1 | — | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 13 | $S_5$ | 101 | 0 | — | 0 | — | — | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | | 101 | 0 | — | 1 | — | — | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 15 | | 101 | 0 | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 16 | | 101 | 1 | — | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 17 | | 110 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 18 | | 111 | — | — | — | — | — | — | — | — | — | — | — | — | — |



# Output & Next-State Equations

- Derive equations for the ***control signals*** and the ***next state*** equations from the state transition table by:
  1. use the ***K-map w/ map-entered variables*** method
  2. use a ***CAD program***, e.g., *LogicAid*
  3. ***track link paths*** on the SM chart and simplify the resulting equations using the "don't care" next state

* We choose the first method.

# K-map with Map-Entered Variables

- K-maps for $A^+$, $B^+$, $Win$:
  - ***A***, ***B***, ***C***, and ***Rb*** have assigned values in most of the rows of the state transition table.
    $\Rightarrow$ Use these 4 variables on the map edges & the remaining variables are entered within the map.

State transition table

| | ABC | Rb | Reset | $D_7$ | $D_{711}$ | $D_{2312}$ | Eq | $A^+$ | $B^+$ | $C^+$ | Win | Lose | Roll | Sp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 000 | 0 | — | — | — | — | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 000 | 1 | — | — | — | — | — | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 3 | 001 | 1 | — | — | — | — | — | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 4 | 001 | 0 | — | — | 0 | 0 | — | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 5 | 001 | 0 | — | — | 0 | 1 | — | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 6 | 001 | 0 | — | — | 1 | — | — | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | 010 | — | 0 | — | — | — | — | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 8 | 010 | — | 1 | — | — | — | — | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 9 | 011 | — | 1 | — | — | — | — | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 10 | 011 | — | 0 | — | — | — | — | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 11 | 100 | 0 | — | — | — | — | — | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 100 | 1 | — | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 13 | 101 | 0 | — | 0 | — | — | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 101 | 0 | — | 1 | — | — | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 15 | 101 | 0 | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 16 | 101 | 1 | — | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 17 | 110 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 18 | 111 | — | — | — | — | — | — | — | — | — | — | — | — | — |



- For $A^+$:

$E_1 = D_{711}' \, D_{2312}'$

$E_2 = D_7' Eq'$

| | ABC | Rb | Reset | $D_7$ | $D_{711}$ | $D_{2312}$ | Eq | $A^+$ | $B^+$ | $C^+$ | Win | Lose | Roll | Sp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 000 | 0 | — | — | — | — | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 000 | 1 | — | — | — | — | — | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 3 | 001 | 1 | — | — | — | — | — | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 4 | 001 | 0 | — | — | 0 | 0 | — | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 5 | 001 | 0 | — | — | 0 | 1 | — | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 6 | 001 | 0 | — | — | 1 | — | — | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | 010 | — | 0 | — | — | — | — | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 8 | 010 | — | 1 | — | — | — | — | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 9 | 011 | — | 1 | — | — | — | — | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 10 | 011 | — | 0 | — | — | — | — | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 11 | 100 | 0 | — | — | — | — | — | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 100 | 1 | — | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 13 | 101 | 0 | — | 0 | — | — | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 101 | 0 | — | 1 | — | — | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 15 | 101 | 0 | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 16 | 101 | 1 | — | — | — | — | — | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 17 | 110 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 18 | 111 | — | — | — | — | — | — | — | — | — | — | — | — | — |

| CRb \ AB | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | × | 1 |
| 01 | | | × | 1 |
| 11 | | | × | 1 |
| 10 | $E_1$ | | × | $E_2$ |

$A^+$

$$= AC' + A\,Rb + A'B'C\,Rb'\,E_1 + A\,E_2$$

$$= AC' + A\,Rb + A'B'C\,Rb'\,D_{711}'\,D_{2312}' + A\,D_7'\,Eq'$$

|  | ABC | Rb | Reset | $D_7$ | $D_{711}$ | $D_{2312}$ | Eq | $B^+$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 000 | 0 | — | — | — | — | — | 0 |
| 2 | 000 | 1 | — | — | — | — | — | 0 |
| 3 | 001 | 1 | — | — | — | — | — | 0 |
| 4 | 001 | 0 | — | — | 0 | 0 | — | 0 |
| 5 | 001 | 0 | — | — | 0 | 1 | — | 1 |
| 6 | 001 | 0 | — | — | 1 | — | — | 1 |
| 7 | 010 | — | 0 | — | — | — | — | 1 |
| 8 | 010 | — | 1 | — | — | — | — | 0 |
| 9 | 011 | — | 1 | — | — | — | — | 0 |
| 10 | 011 | — | 0 | — | — | — | — | 1 |
| 11 | 100 | 0 | — | — | — | — | — | 0 |
| 12 | 100 | 1 | — | — | — | — | — | 0 |
| 13 | 101 | 0 | — | 0 | — | — | 0 | 0 |
| 14 | 101 | 0 | — | 1 | — | — | 0 | 1 |
| 15 | 101 | 0 | — | — | — | — | 1 | 1 |
| 16 | 101 | 1 | — | — | — | — | — | 0 |
| 17 | 110 | — | — | — | — | — | — | — |
| 18 | 111 | — | — | — | — | — | — | — |

- For $B^+$:

$E_3 = D_{711} + D_{711}' D_{2312}$
$= D_{711} + D_{2312}$

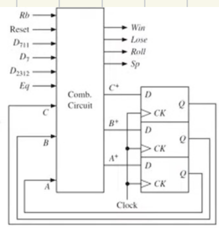
$E_4 = E_q + E_q' D_7 = E_q + D_7$

$R = \text{Reset}$

| CRb \ AB | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 |  | $R'$ | × |  |
| 01 |  | $R'$ | × |  |
| 11 |  | $R'$ | × |  |
| 10 | $E_3$ | $R'$ | × | $E_4$ |

$B^+$
$= A'B'C\ Rb'\ E_3 + B\ R' + AC\ Rb'\ E_4$
$= A'B'C\ Rb'(D_{711}+D_{2312}) + B\ Reset'$
$+ AC\ Rb'(Eq + D_7)$






- Resulting equations:

$A^+ = AC' + A\ Rb +$
$+ A'B'C\ Rb'\ D_{711}'\ D_{2312}' + A\ D_7'\ Eq'$

$B^+ = A'B'C\ Rb'(D_{711}+D_{2312}) + B\ Reset'$
$+ AC\ Rb'(Eq + D_7)$

$C^+ = B'\ Rb + A'B'C\ D_{711}'\ D_{2312} + BC\ Reset'$
$+ AC\ D_7\ Eq'$

$Win = BC'$

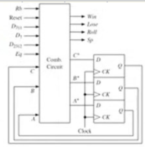
$Lose = BC$

$Roll = B'C\ Rb$

$Sp = A'B'C\ Rb'\ D_{711}'\ D_{2312}'$

# Implementations

Comb ckt:
9 inputs, 7 outputs



- These equations can be implemented in any standard technology (using discrete ***gates***, ***PALs***, ***GALs***, ***CPLDs***, or ***FPGAs***).
- The controller can also be realized using a ***ROM***: ROM (***LUT***) implementation
  - needs 512 entries (9 inputs) and each entry must be 7 bits wide $\Rightarrow 2^9 \times 7$ ROM
  - The ROM method is not very desirable for state machines w/ a large # of inputs.