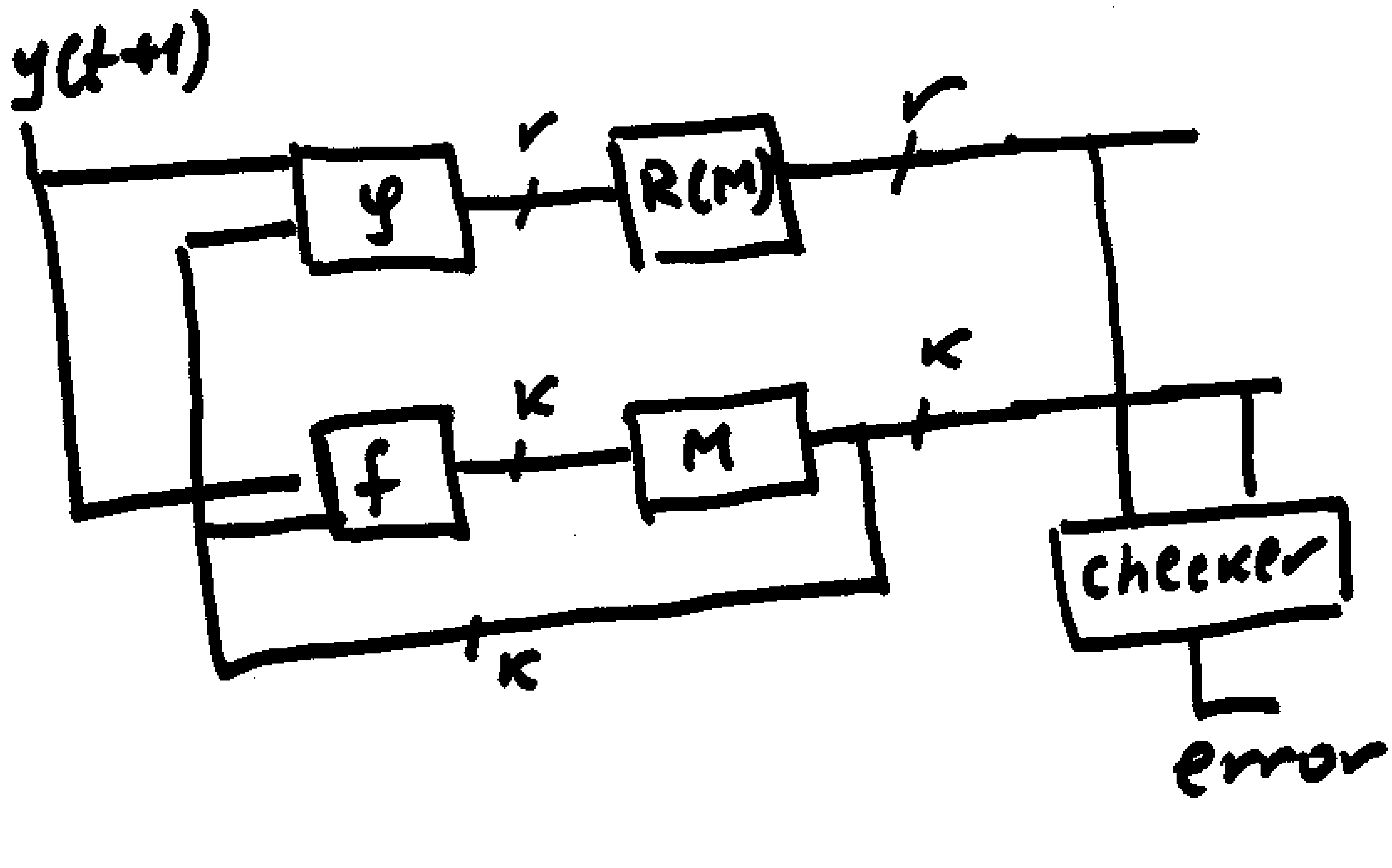
On-Line Testing of Sequential Devices

(General case)

$$\left.\begin{aligned} s(t+1) &= f(y(t+1), s(t)) \\ z(t+1) &= s(t+1) \end{aligned}\right\} \text{ORIGINAL DEVICE}$$

$$R(s(t+1)) = R(f(y(t+1), s(t))) =$$
$$= f(y(t+1), s(t)) \cdot P$$
$$= \varphi(y(t+1), s(t))$$

$s(t) \in \{0,1\}^k$, $R(s(t)) \in \{0,1\}^r$



Sequential Fault-Tolerant networks

Abstract synthesis

State ~~Assignme~~ Assignment for Internal States by Codewords of Error Correcting / Detecting Codes.

Example Correction of single errors $l_c = 1$

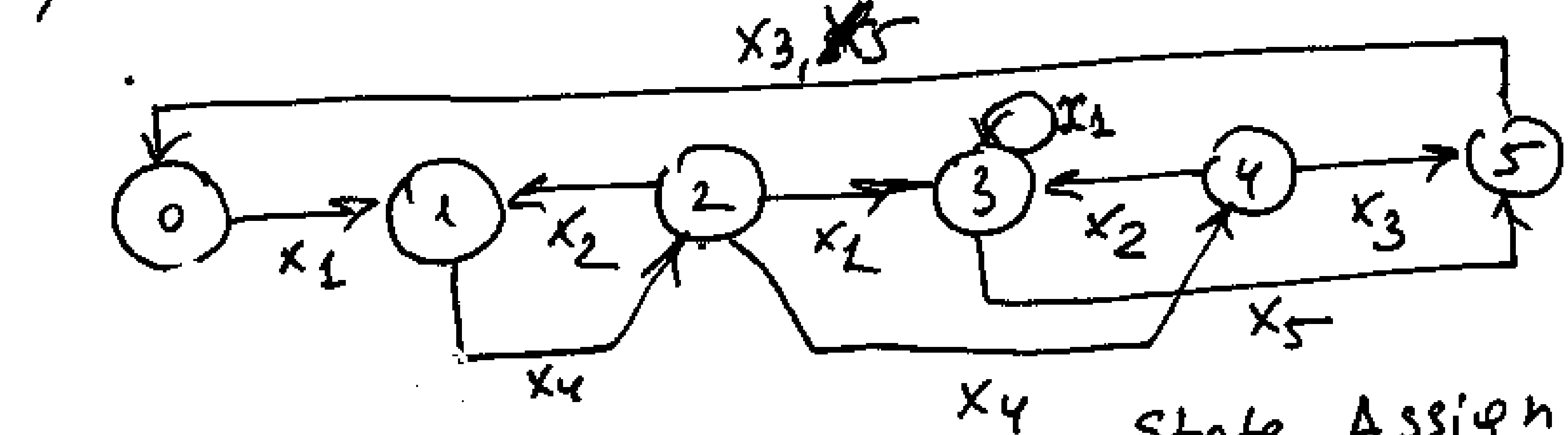
Number of redundand FFs

r, where $r \geq \log_2 (K + r + 1)$

n_a - is a number of internal states. $K = \lceil \log_2 n_a \rceil$

Example $l_c=1$ Inputs assumed to be fault-free

1)



$$H=\begin{bmatrix}0&1&1&1&0&0\\1&0&1&0&1&0\\1&1&0&0&0&1\end{bmatrix} \qquad G=\begin{bmatrix}1&0&0&0&1&1\\0&1&0&1&0&1\\0&0&1&1&1&0\end{bmatrix}$$

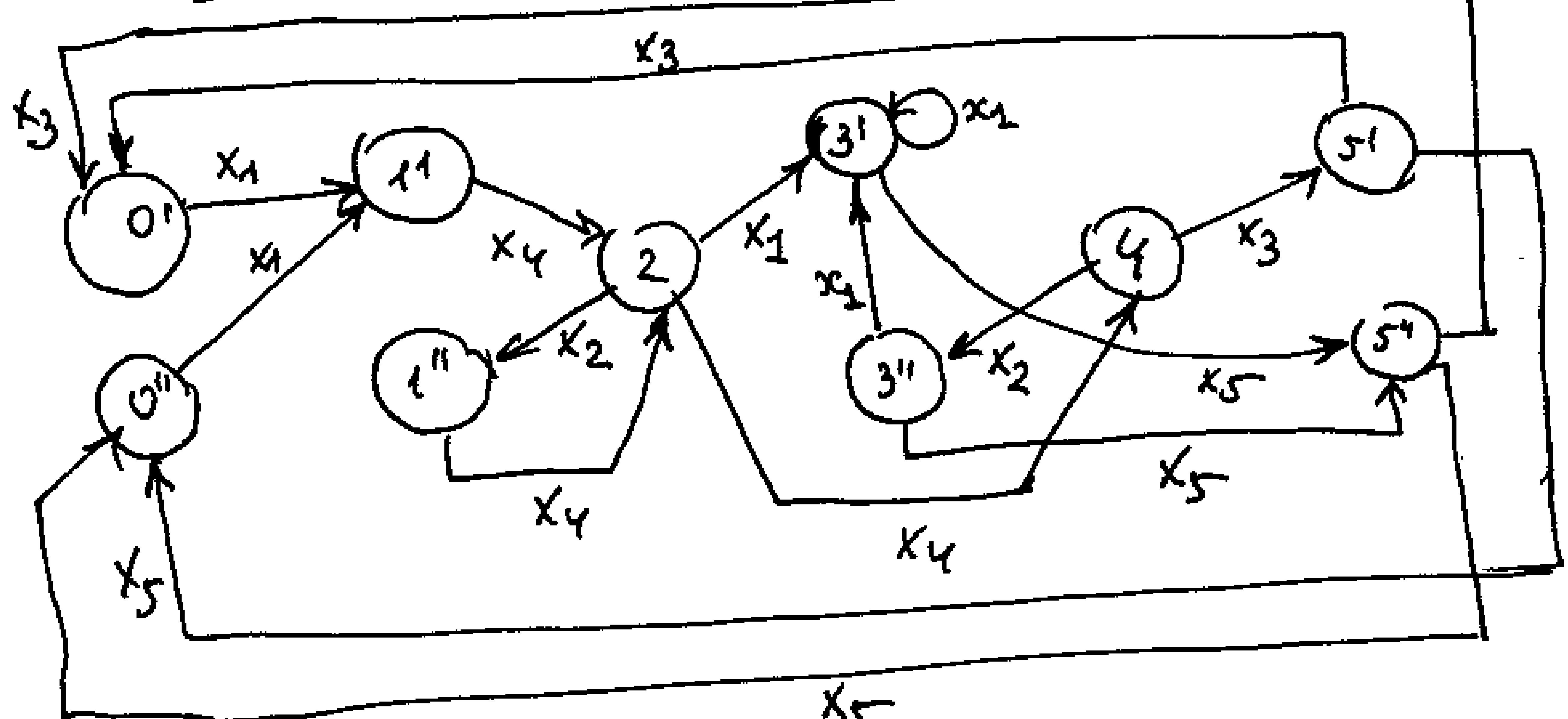
Total # of FFs = 6

State Assignment

0 – 000 000
1 – 100 011
2 – 010 101
3 – 110 110
4 – 001 110
5 – 101 101
6 – 011 011

$K=3$
$r=3$

2). Splitting Internal States
Redundancy at the abstract leve (The same example)



State Assignment

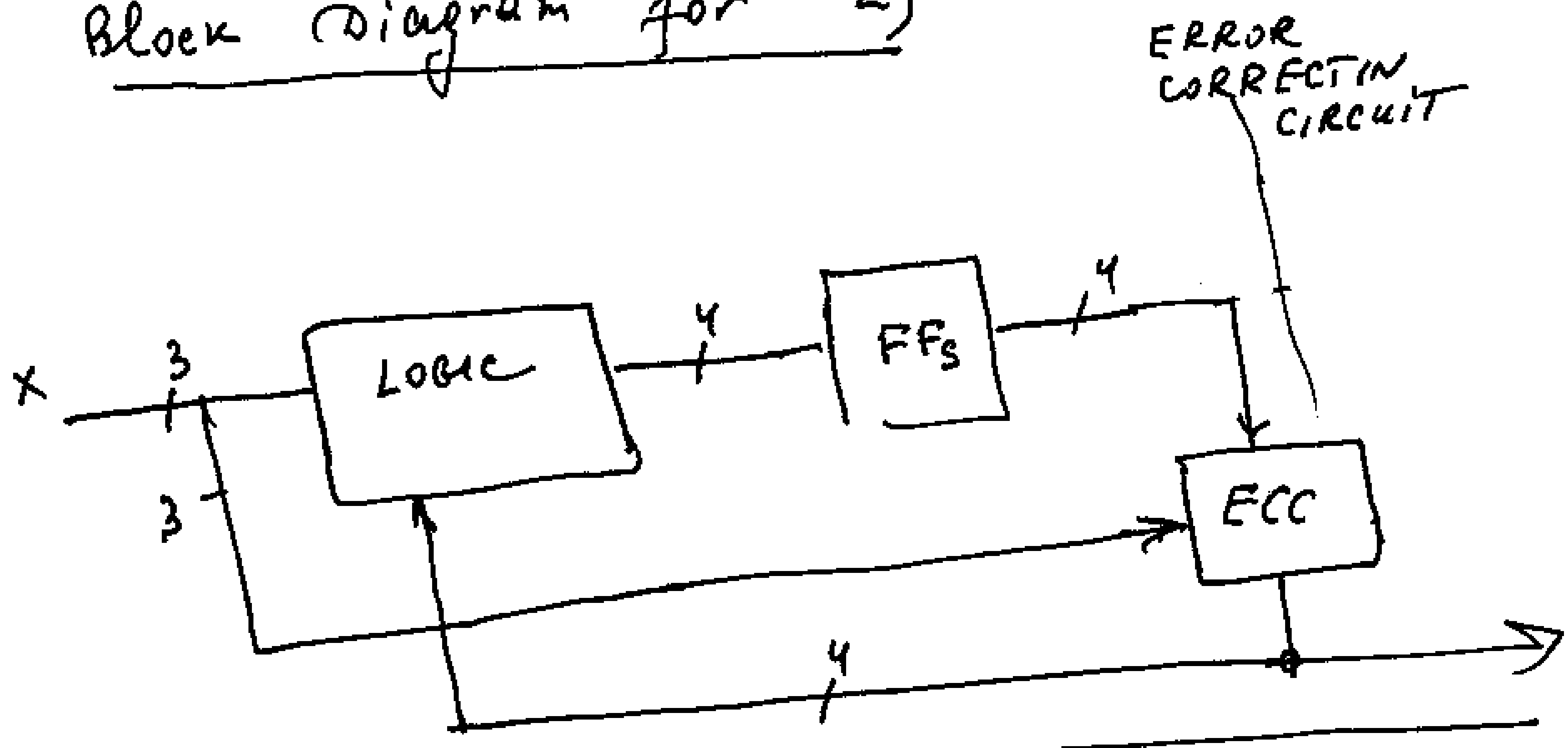
0' – 0000 } FOR INPUT x_3
5' – 0111 }
0'' – 0001 } FOR x_5
5'' – 0110 }
1' – 0010 } FOR x_1
3' – 0101 }

1'' – 0100 } For x_2
3'' – 0011 }

2 – 1000 } For x_4
4 – 1111 }

Total # of FFs = 4

Block Diagram for 2)



3) Partial SPLITTING OF INTERNAL STATES

Select the following grouping of INPUTS

$\lambda_0 = (\{x_1, x_2\}, \{x_3, x_5\}, \{x_4\})$. Then (no splitting for this example)

STATE ASSIGNMENT

0 – 000 } For $\{x_3, x_5\}$
5 – 111

1 – 001 } For $\{x_1, x_2\}$
3 – 110

2 – 010 } FOR $\{x_4\}$
4 – 101

Total # of FF = 3

optimal number of FFs is the same as for the case when no error correction

The same block-diagram as in 2)

For 3) we split only those internal states which are reachable by inputs from different blocks of the grouping (no splitting for λ_0)

Minimization of a number of FFs by optimal selection of a grouping of inputs

Denote $\mathbb{1} = \{x_1, x_2, x_3, x_4, x_5\}$

$\mathbb{0} = (\{x_1\}, \{x_2\}, \{x_3\}, \{x_4\}, \{x_5\})$

For two groupings λ_1 and λ_2 we denote $\lambda_1 \geq \lambda_2$ if blocks of λ_2 are subsets of blocks of λ_1

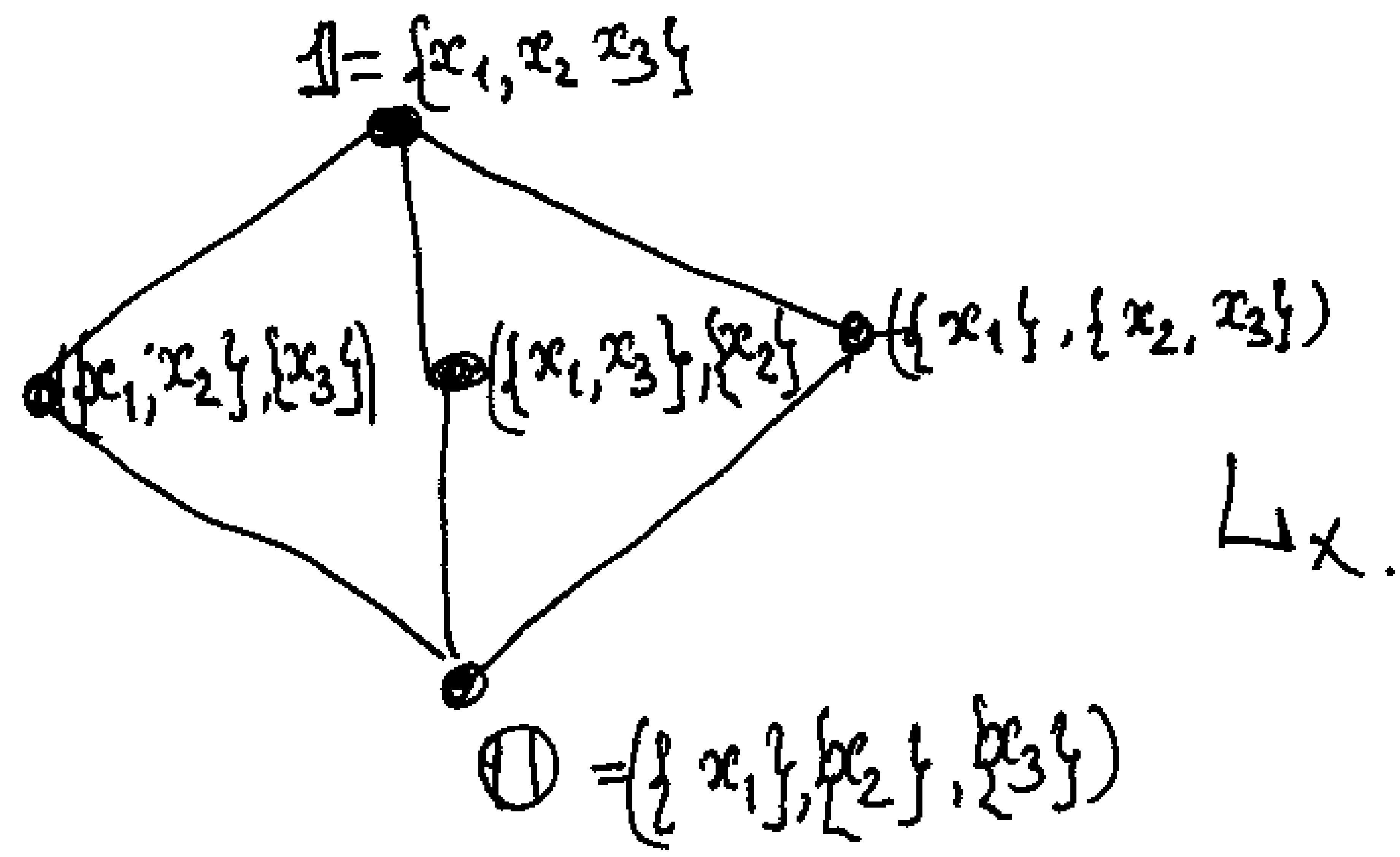
$(\{x_1, x_2, x_3\}, \{x_4, x_5\}) \geq (\{x_1, x_2\}, \{x_3\}, \{x_4, x_5\})$

For any λ : $\mathbb{0} \leq \lambda \leq \mathbb{1}$

Set of groupings λ form ~~an~~ partially ordered set called <u>lattice</u>.

We denote this lattice L_x

For 3 inputs x_1, x_2, x_3



Denote $n(\lambda)$ total number of FFs required for grouping λ

For the previous example

λ	$\mathbb{I}$	$\mathbb{O}$	λ_0
$n(\lambda)$	6	4	3

For $l_c = 1$

$$n(\mathbb{I}) = \lceil \log_2 n_a \rceil + r$$

where

$$r \geq \log_2 (\lceil \log_2 n_a \rceil + r + 1)$$

Problem: find

$$\min_{\lambda \in L_x} n(\lambda)$$

Minimization of a function defined on the lattice L_x.

For the example

$$\min_{\lambda \in L_x} n(\lambda) = n(\lambda_0) = 3$$