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CONTRIBUTIONS TO STATE IDENTIFICATION OF A SEQUENTIAL SYSTEM

BY

ALEXANDRU VALACHI and GRIGORE MIHAI TIMIŞ*

“Gheorghe Asachi” Technical University of Iaşi,
Faculty of Automatic Control and Computer Engineering

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Abstract. In this paper, the authors proposed a case study contribution for identifying the states of a sequential digital system. A comprehensive study for optimal identification of sequential digital system states is developed and a new algorithm to reduce the number of these states is proposed.

Key words: digital systems; sequential systems; states identification; moore machine; mealy machine; equivalent states; timing diagram; fluence table; states diagram.

1. Introduction

In the following, we are analyzing the method for detecting the states of a digital automata described by the timing diagrams. The original method is described by Corner, (1995) and Roth, (1992).

We use the output signal

$$z_n = f(x_{n,\,t}),$$

where: z_n represents the output variables, x_n – the input variables, t – the time.

Using the timing diagram, we will identify the system’s states and then build the states diagram.

*Corresponding author: *e-mail*: mtimis@tuiasi.ro

2. Case Study Example

As the case study example, we will use the following timing diagram, Fig. 1.

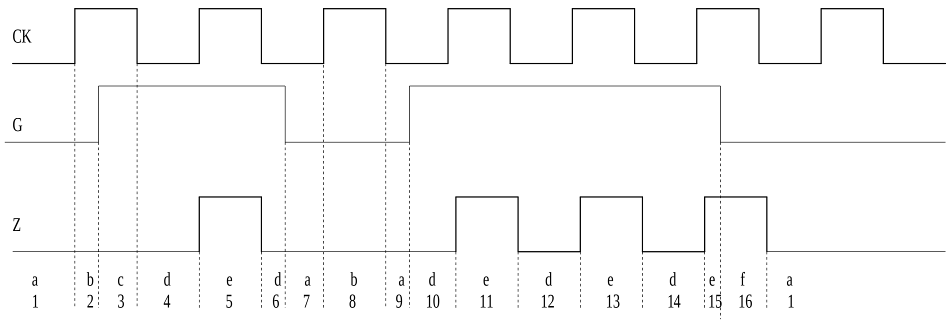

Fig. 1 – Timing diagram.

We noted with (a) the initial state. The states diagram which results from the timing diagram is shown in Fig. 2. We noticed that it is different from those by Comer, ((1995), Figs. 10 and 13).

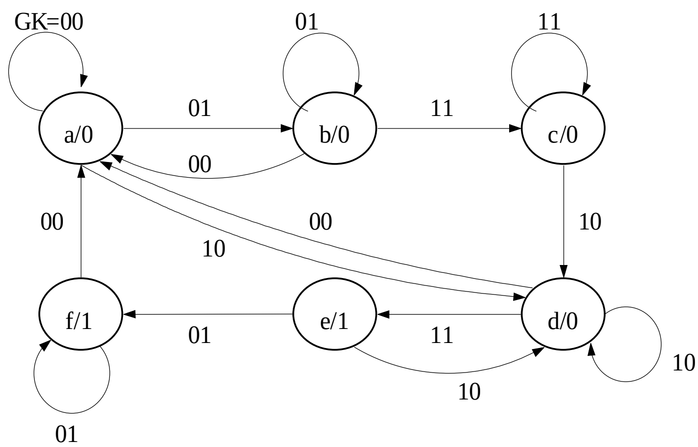

Fig. 2 – States diagram.

Using the states diagram, the transition matrix is derived, Table 1.

We will define (*p*) equivalent states if they have the same value of the output vector and the same next state values.

Following this rule, it is obtained the following sets of equivalent states (*a*, *b*, *c*), (*e*, *f*).

If these equivalent states will be labelled like in Eq. (1), the resulting reduced matrix table will be the one shown in Table 2.

Table 1
Transition Matrix

Pres. state \ G CK	00	01	11	10	*z*
a	*a*	*b*	Φ	*d*	0
b	*a*	*b*	*c*	Φ	0
c	Φ	Φ	*c*	*d*	0
d	*a*	Φ	*e*	*d*	0
e	Φ	*f*	*e*	*d*	1
f	*a*	*f*	Φ	Φ	1

Table 2
Reduced Transition Matrix

Pres. state \ G CK	00	01	11	10	*z*
1	1	1	1	2	0
2	1	Φ	3	2	0
3	1	3	3	2	1

$$\begin{aligned} &(a,b,c)\equiv 1\\ &(e,f)\equiv 3\\ &d\equiv 2 \end{aligned} \tag{1}$$

Using the states coding like in (Comer, 1995) and additionally using the transition from the 4th state to initial one (00), the following transition matrix shown in Table 3 is obtained.

Table 3
Transition Matrix (codification states)

Pres. state \ G CK	00	01	11	10	*z*
1 – 00	00	00	00	01	0
2 – 01	00	Φ Φ	11	01	0
3 – 11	00	11	11	01	1
4 – 10	00	00	00	00	0

Using the Veitch-Karnaugh diagrams for the minimization of equations, expressions (2) are obtained.

$$\begin{aligned} &z_n=(y_1y_0)_n;\\ &y_{1,n+1}=(\mathrm{CK}\cdot y_0)_n;\\ &y_{0,n+1}=(\mathrm{CK}\cdot y_0+\overline{\mathrm{CK}}\cdot \mathrm{G}\cdot \overline{y_1})_n. \end{aligned} \tag{2}$$

One of the possible implementation using only the elementary logic gates is presented in Fig. 3. Notice that this circuit different than those obtained by the (Comer, 1995).

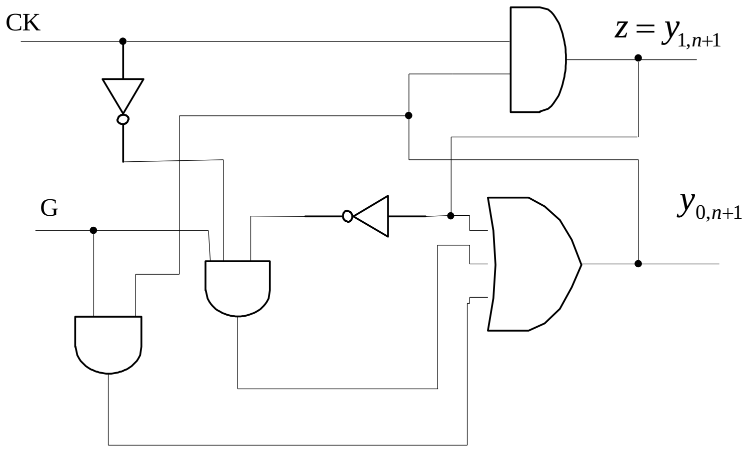

Fig. 3 – Implementation of Eq. (2) with logic gates.

Following our design proposal and those described by Roth, (1992), it can be observed that the build of the graph states diagram starting directly from the timing diagrams can generate errors.

In addition, the authors consider that design obtained by Roth, (1992) is wrongly done, as:

- The automata type is Mealy instead Moore
- The state to which system transition from the 4 state is considered Φ, for states minimization purposes and hardware minimization. Practically, it should be considered the first state (reset state –00). The output signal values should be deactivated.

3. Contribution Proposal

The new proposed method consists of avoiding the build of state diagram like it was done in (C.Roth, 1992), (D. Comer, 1995) since it can introduce errors.

So, the new method consists of the following steps:

1. The states from timing diagram are assigned from left to right using the following order: 1, 2, 3,…, *k*.
2. The transition table is build.
3. Searching for the states that can be reduced.

The following Lema is proposed by the authors.

Lema: Two or more states are equivalent if the output vector values are the same within the same column, are stable and the next states are also the same or indifferent.

Using the Lema, the initial build for the transition matrix will be considered. The states will be labeled with symbols (1), (2), (3),….,(16). The transition matrix will be obtained, as described in Table 4.

Table 4
Transition Matrix

G CK / Pres. state	00	01	11	10	*z*
1	1	2	Φ	Φ	0
2	Φ	2	3	Φ	0
3	Φ	Φ	3	4	0
4	Φ	Φ	5	4	0
5	Φ	Φ	5	6	1
6	7	Φ	Φ	6	0
7	7	8	Φ	Φ	0
8	9	8	Φ	Φ	0
9	9	Φ	Φ	10	0
10	Φ	Φ	11	10	0
11	Φ	Φ	11	12	1
12	Φ	Φ	13	12	0
13	Φ	Φ	13	14	1
14	Φ	Φ	15	14	0
15	Φ	16	15	Φ	1
16	1	16	Φ	Φ	1

Using the transition matrix, the following states equivalence is obtained: (1, 7, 9) states are equivalent because $Z = 0$, $G \cdot CK = 00$ and states (2, 8) are equivalent. Following this, we obtain the new reduced transition matrix, given in Table 5 with new reassigned states:

$$\begin{aligned} &(1,7,9) = a \\ &(2,8) = b \\ &3 = c \\ &(4,6,10,12,14) = d \\ &(5,11,13,15) = e \\ &16 = f \end{aligned} \tag{3}$$

Table 5
Reduced Transition Matrix

G CK / Pres. state	00	01	11	10	z
a	*a*	*b*	Φ	*d*	0
b	*a*	*b*	*c*	Φ	0
c	Φ	Φ	*c*	d	0
d	*a*	Φ	*e*	d	0
e	Φ	*f*	*e*	*d*	1
f	*a*	*f*	Φ	Φ	1

Using the previous defined Lema and the reduced transition matrix from Table 5, we relabel the states as following:

$$\begin{aligned} (a,b,c) &= a \\ d &= b \\ (e,f) &= c \end{aligned} \tag{4}$$

The final transition matrix is obtained, Table 6.

Table 6
Final Reduced Transition Matrix

G CK / Pres. state	00	01	11	10	*z*
a	*a*	*b*	*a*	*b*	0
b	*a*	Φ	*c*	*b*	0
c	*a*	*c*	*c*	*b*	1

Using the same coding like in Table 3, we obtain the same implementation as in Fig. 3.

4. Conclusions

Starting from the example analysed in (Roth, 1992; Comer, 1995), building the primary fluence graph was avoided because this can introduce errors.

The states identification starts with numbering all distinct states.

The transition matrix is build using the timing diagram signals values.

Iterative states reduction is done from the transition matrix using our Lema.

The new proposed method for states identification and reduction is much easy to use than those described in (Mano, 2002).

5. Improving Directions and Further Developments

1º In this paper, the authors present only states identification of the Moore sequential systems using the timing diagram signals.

2º A possible further research theme consists of new analysis methods for the sequential systems using functional cycles, sequence strings, (Kamel *et al.*, 2002; Yogesh *et al.*, 2015; Valachi *et al.*, 2013; Ursaru *et al.*, 2009).

The proposed implementation was done using only logic gates, but flip-flop circuits, digital programmable structures, FPGAs, can further be used (Tinder *et al.*, 2000; Barkalov *et al.*, 2011).

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CONTRIBUŢII PRIVIND IDENTIFICAREA STĂRILOR UNUI SISTEM SECVENŢIAL

(Rezumat)

În această lucrare, autorii prezintă contribuţia proprie cu privire la identificarea şi reducerea numărului de stări a unui sistem secvenţial descris prin diagramele de semnal aferente. Această metodă permite construirea tabelului de fluenţă plecând de la această diagramă de semnale. Ţinând cont de definiţia stărilor echivalente, printr-o scanare vizuală a tabelului primitiv de tranziţie, se obţine reducerea numărului de stări, astfel rezultând o implementare optimală a sistemului secvenţial propus. Algoritmul propus de autori constă în evitarea construcţiei grafului de fluenţă ce poate duce la erori, (Comer *et al.*, 1995) şi realizarea tabelei de tranziţie plecând de la diagramele de semnal.