Application Note

How to replace CD40xx ICs with GreenPAK

AN-CM-235

Abstract

This application note describes the behavior and operation of several ICs of the CD40XX family, and how to implement their functionality using the SLG46880 or the SLG46533.
This application note comes complete with design files which can be found in the References section.

Contents

Figures

Tables

1 Terms and Definitions

ASM   Asynchronous state machine

CMICs   Configurable mixed-signal integrated circuits

ICs   Integrated circuits

2 References

For related documents and software, please visit:

https://www.dialog-semiconductor.com/configurable-mixed-signal.

Download our free GreenPAK Designer software [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Dialog Semiconductor provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the Dialog IC.

[1]   GreenPAK Designer Software, Software Download and User Guide, Dialog Semiconductor

[2]   AN-CM-235 How to Replace CD40xx ICs with GreenPAK.gp, GreenPAK Design File, Dialog Semiconductor

[3]   GreenPAK Development Tools, GreenPAK Development Tools Webpage, Dialog Semiconductor

[4]   GreenPAK Application Notes, GreenPAK Application Notes Webpage, Dialog Semiconductor

3   Introduction

The CD40XX family of Integrated Circuits (ICs) are some of the most commonly used ICs by electronic enthusiasts. Most of these ICs are sold in a DIP through-hole package, which makes them easy to implement and affordable enough to be attractive for electronic enthusiasts. Most CD40XX ICs have a singular function, which means a designer may need several of them to perform tasks that require more than one process.

Dialog SLG46880 and SLG46533 Configurable Mixed-signal Integrated Circuits (CMICs), are excellent substitutes for most, if not all, of the CD40XX ICs. In this application note, we'll explore the behavior and operation of several ICs of the CD40XX family, and how we can implement their functionality using the SLG46880 or the SLG46533.

The SLG46880 has an internal Asynchronous State Machine (ASM). However, unlike other GreenPAK™ devices like the SLG46537 and SLG46538, the SLG46880's ASM has 12 states rather than 8. These additional states allow us to drive displays, and the amount of Look-Up Tables (LUTs) is well suited to develop a decent number of parallel tasks. Despite the increased functionality, the SLG46880 remains a low power solution.

Figure 1: CD4008 IC

4   Replacing the CD4008

We'll start by discussing how to use the GreenPAK to replace the CD4008, a 4-bit full adder which is able to add together two 4-bit binary numbers.

First, we should explain how to execute the binary adding operation, and how to implement it using LUTs (look up tables).

$$
\begin{aligned}
A\ &1001 \\
B\ &\underline{0001} \\
S\ &1010
\end{aligned}
$$

In the equation above, the least significant bits of A and B are both 1, and the least significant bit of S is 0. The next least significant bit for both A and B is 0, yet the corresponding value of S is 1. As with decimal addition, this is because of a "carry" bit, which goes to the next binary value to continue with the operation.

Using these principles, we can make a truth table to explain how the system should work as it is shown in Table 1.

How to replace CD40xx ICs with GreenPAK

Table 1: Truth Table

Inputs			Outputs	
A	**B**	**C$_{IN}$**	**C$_{OUT}$**	**S**
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

Figure 2 shows the logic circuit typically used to implement the adding operation for 1 bit.
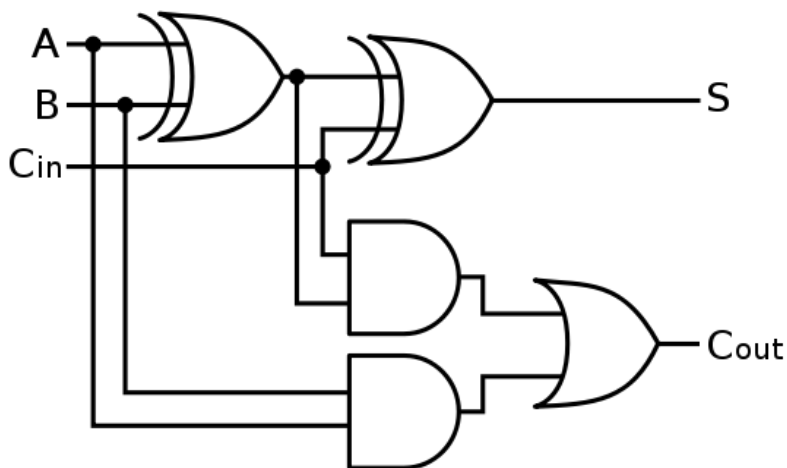

Figure 2: Schematic for a 1-bit Full Adder

The GreenPAK implementation of the CD4008 is shown in Figure 3
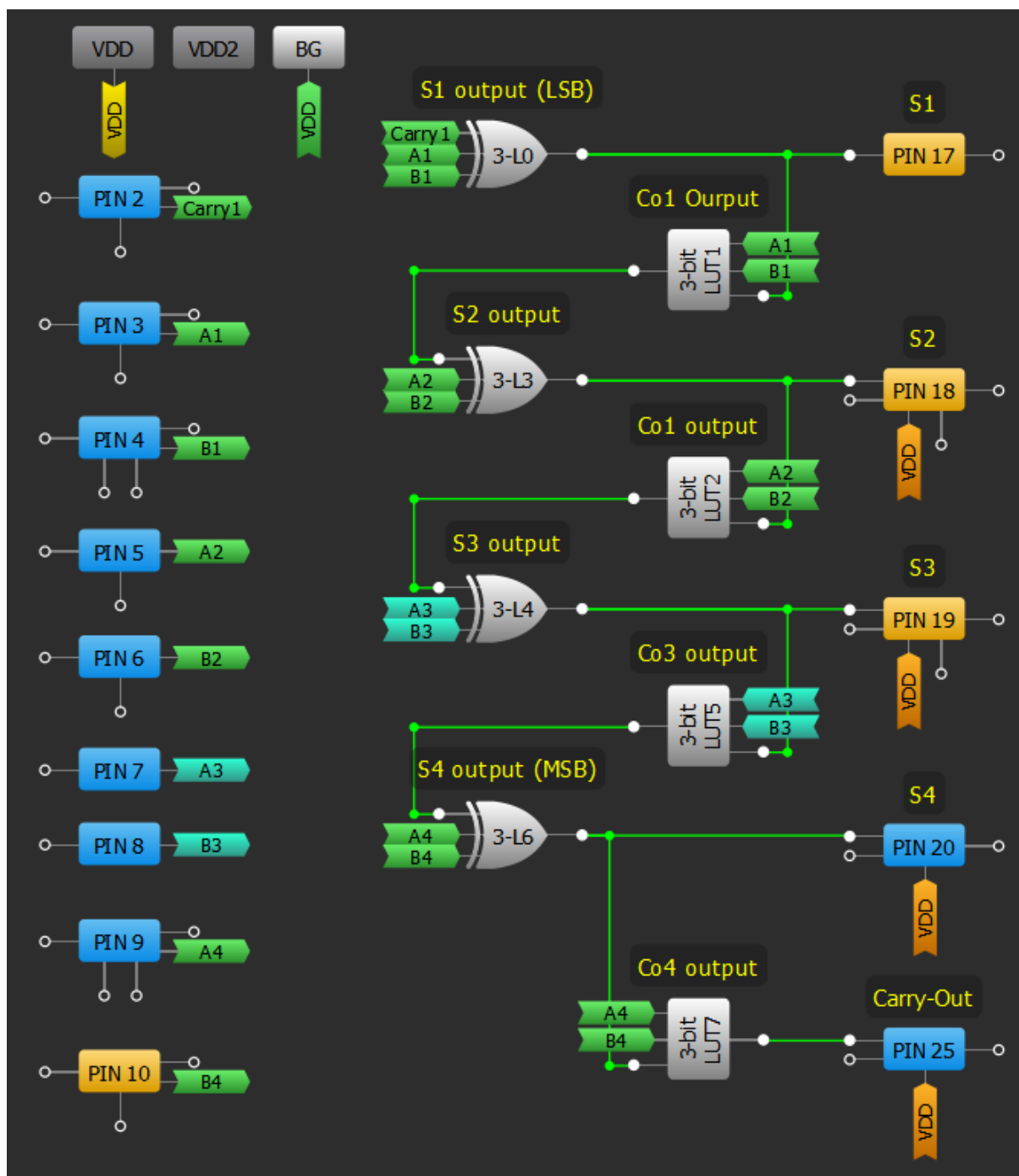
How to replace CD40xx ICs with GreenPAK

Figure 3: CD4008 Implemented in a GreenPAK

CD4008 ICs are not commonly used anymore, but being able to implement their functionality in a GreenPAK makes it competitive with newer 4-bit full adder ICs. For example, the SN74LS283NSR IC costs up to $2 USD for one piece and $1.16 USD in orders of more than 500 pieces. The GreenPAK SLG46880 is well under that price, and it contains several more components that could be used to implement additional functionality.

5   Replacing the CD4028

The next IC we are going to implement is the CD4028, a binary-coded decimal to decimal converter. It has four binary inputs, used to decode the binary-coded decimal into a single output, one of ten possible outputs from 0 to 9.

This IC is typically composed of several logic gates, as shown in Figure 2. The versatility of Dialog's GreenPAKs let us implement this functionality easily, by using configurable LUTs.
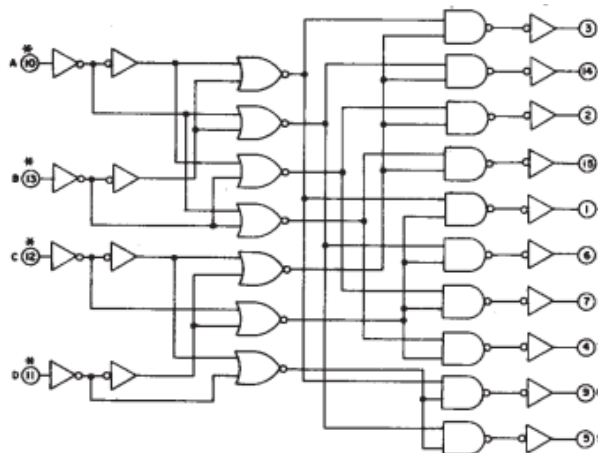

Figure 4: Schematic for the CD4028

To create this system, we need to implement the truth table shown in Table 2.

Table 2: Truth Table for the CD4028

D	C	B	A	0	1	2	3	4	5	6	7	8	9
0	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0	0	0	0	0	0
0	0	1	0	0	0	1	0	0	0	0	0	0	0
0	0	1	1	0	0	0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0	1	0	0	0	0	0
0	1	0	1	0	0	0	0	0	1	0	0	0	0
0	1	1	0	0	0	0	0	0	0	1	0	0	0
0	1	1	1	0	0	0	0	0	0	0	1	0	0
1	0	0	0	0	0	0	0	0	0	0	0	1	0
1	0	0	1	0	0	0	0	0	0	0	0	0	1
1	0	1	0	0	0	0	0	0	0	0	0	0	0
1	0	1	1	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	1	0	0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0	0	0	0	0

The CD4028 has around 30 logic gates to convert the BCD to a decimal value, but the GreenPAK™ 6 achieves this with 10 LUTs. Plus, resources like the ASM and a few LUT tables are still available to use. In Figure 5 we can see the implementation in GreenPAK™ designer.
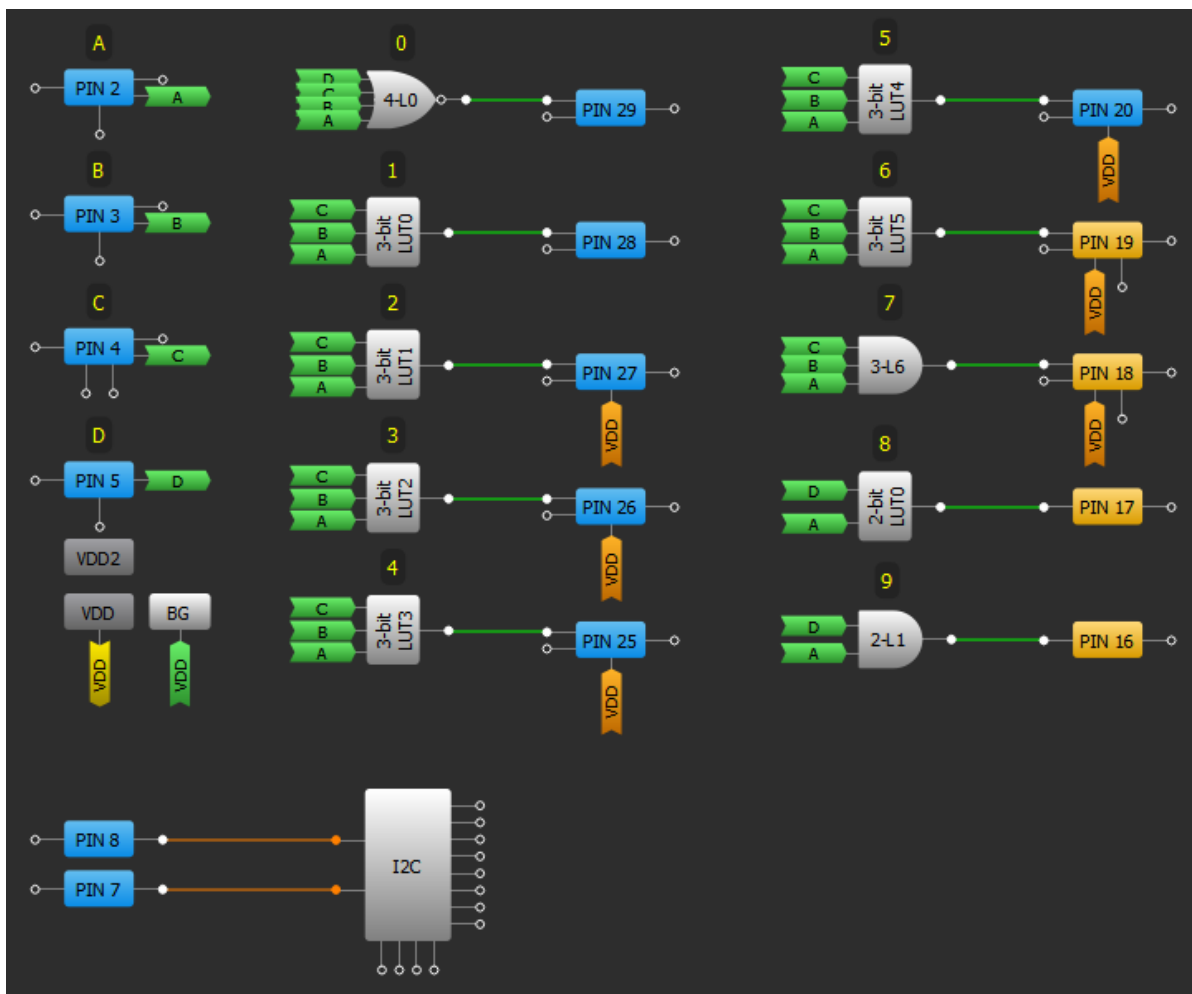
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Figure 5: GreenPAK Design for the CD4028

6   Replacing the CD4024

Next up is the CD4024, a ripple counter that's mainly used as a frequency divider. With seven stages, we can divide the input clock by a factor of up to 128. The circuit to implement the CD4024 is shown in Figure 6. We will make the CD4024 inside an SLG46533.
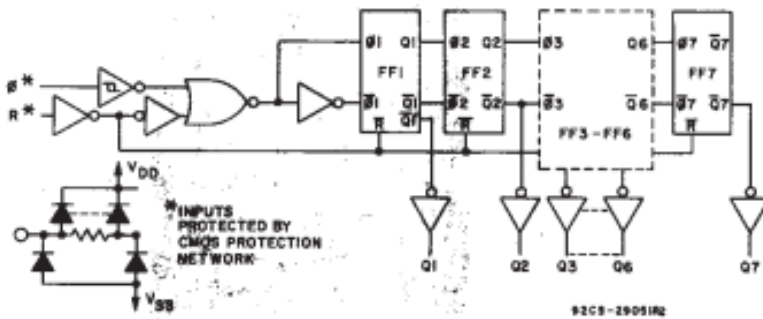

Figure 6: Block Diagram for the CD4024

Based on this IC, we can also build the CD4020 and the CD4040, which are 10 and 14 stages, respectively.

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The CD4024 is mainly used as a frequency divider and can be used to divide the frequency up to 128 times. A logic system equivalent to the one implemented inside the IC was built inside the SLG46533, and is shown in Figure 7.
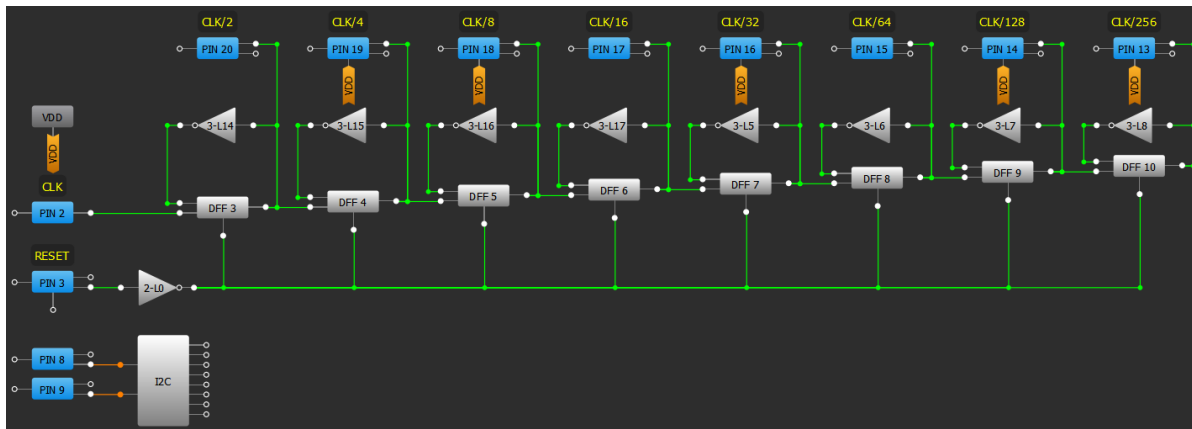

Figure 7: GreenPAK Design for the CD4024

However, this is not the only way to divide frequencies using GreenPAK. Instead, you could simply use a counter block and a DFF block to divide the frequency with a 50% output duty cycle.
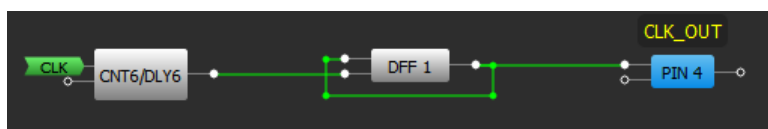

Figure 8: System Diagram

7   Substituting the CD4017

The CD4017 is also a counter, but it's slightly different than the one before, so we'll implement it in the SLG46880 instead of the SLG46533. Its internal implementation (found in the datasheet) signals several differences from the CD4024, CD4020, and CD4040. This can be reviewed in Table 1.
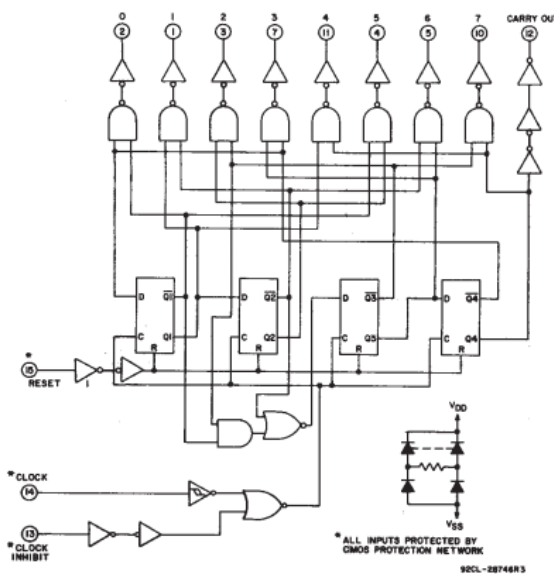

Figure 9: Block Diagram for the CD4017

How to replace CD40xx ICs with GreenPAK

The CD4017 is a 4-stage Johnson counter, capable of counting from 0-7. Likewise, the CD4022 is a 5-stage Johnson counter, which can count from 0-9. Both ICs can easily be implemented in the SLG46880 thanks to its 12-state ASM. Figure 10 shows the logic used to transition between states.
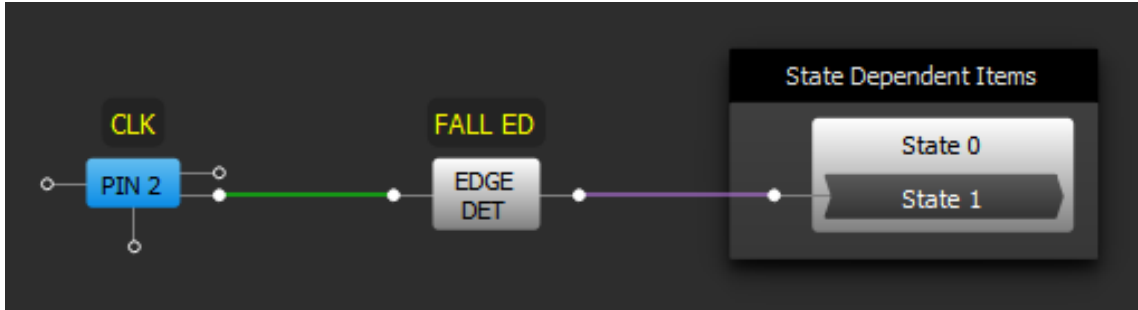

Figure 10: GreenPAK design for the CD4017

The edge detector is used to create a short active high pulse, which causes the State machine to transition from the current state to the next state. The ASM output is shown in Figure 11. Note the activation of a single output for each state.
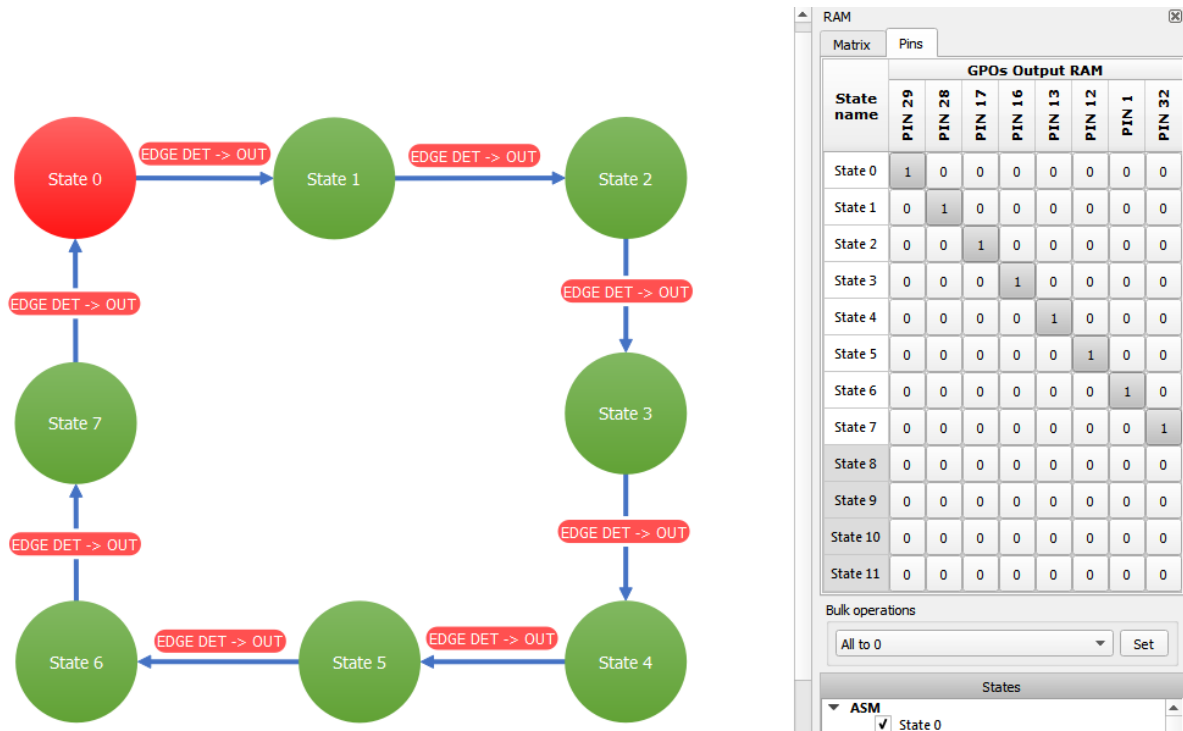

Figure 11: ASM Configuration for the GreenPAK Implementation of the CD4017

8 Replacing simpler CD40XX ICs

There are several circuits inside the CD40XX family that are so simple that they can be easily replicated inside GreenPAK. The following ICs fall under the category as it is shown in Table 3.

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Table 3: CD40XX Family Categories

Part Number	Gate type	Gate Count
CD4001	2-input NOR gates	4
CD4002	4-input NOR gates	2
CD4009	Inverting Buffers	6
CD4010	Non-inverting Buffers	6
CD4011	2-input NAND gates	4
CD4012	4-input NAND gates	2
CD4013	DFFs with Set/Reset	2
CD4023	3-input NAND gates	3
CD4025	3-input NOR gates	3
CD4030	2-input XOR gates	4
CD4070	2-input XOR gates	4
CD4071	2-input OR gates	4
CD4072	4-input OR gates	2
CD4073	3-input AND gates	3
CD4075	3-input OR gates	3
CD4077	2-input XNOR gates	4
CD4081	2-input AND gates	4
CD4082	4-input AND gates	2

The above ICs would be quite simple to replace using logic available in most GreenPAK CMICs.

9   Substituting the CD4543

Last but not least, the CD4543 is a binary-coded decimal (BCD) to 7-segment display. From binary-coded decimal values, we can get the equivalent output for the 7-segment display. This can be achieved by using the State Machine inside the SLG46880.

The design works by rotating through 10 ASM states, labeled ZERO through NINE. These transitions are shown in Figure 12.
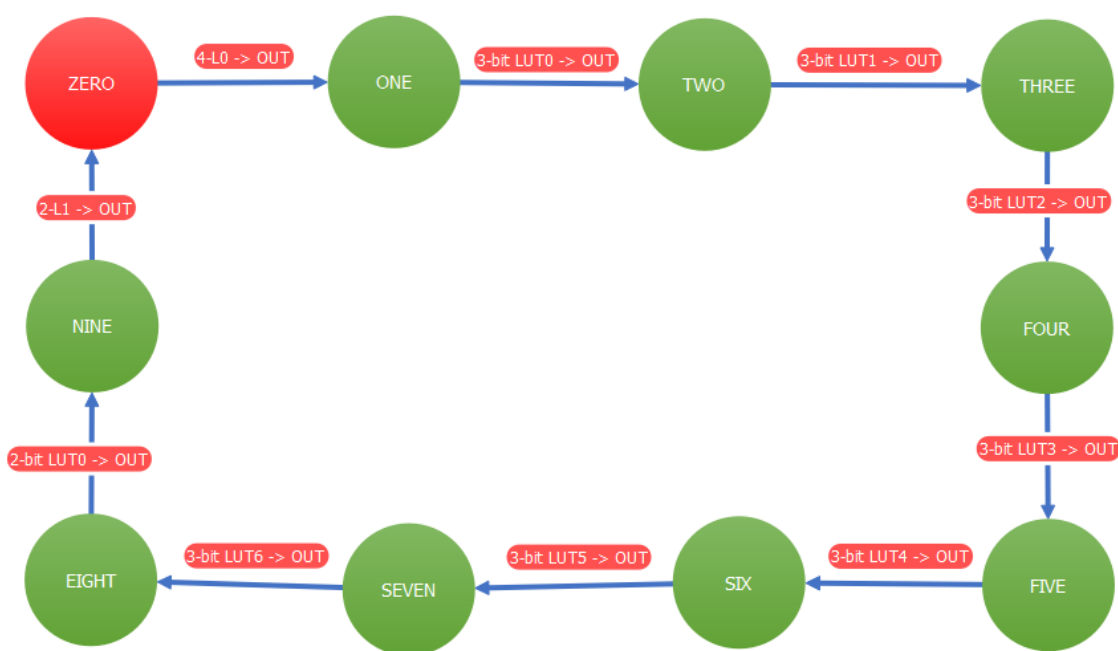

Figure 12: ASM Transition Diagram

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The ASM output ram holds the necessary values for controlling each segment of the 7-Segment display, shown in Figure 13. The ASM will stop rotating when it reaches the state that corresponds to the four input bits, labeled A, B, C, and D in Figure 14. The initial state is ZERO.

State name	PIN 29	PIN 28	PIN 17	PIN 16	PIN 13	PIN 12	PIN 1	PIN 32
ZERO	1	1	1	1	1	1	0	0
ONE	0	1	1	0	0	0	0	0
TWO	1	1	0	1	1	0	1	0
THREE	1	1	1	1	0	0	1	0
FOUR	0	1	1	0	0	1	1	0
FIVE	1	0	1	1	0	1	1	0
SIX	1	0	1	1	1	1	1	0
SEVEN	1	1	1	0	0	0	0	0
EIGHT	1	1	1	1	1	1	1	0
NINE	1	1	1	1	0	1	1	0
State 10	0	0	0	0	0	0	0	0
State 11	0	0	0	0	0	0	0	0

Figure 13: ASM Output RAM

For example, if the inputs are 0010, the ASM will start in state ZERO, but the output of 4-bit LUT0 will be HIGH. This will cause the ASM to transition into state ONE. However, since the output of 3-bit LUT0 will also be HIGH, the ASM will immediately transition into state TWO. At this point the output of 3-bit LUT1 will be LOW, so the ASM will remain in state TWO until the 4 input signals change.
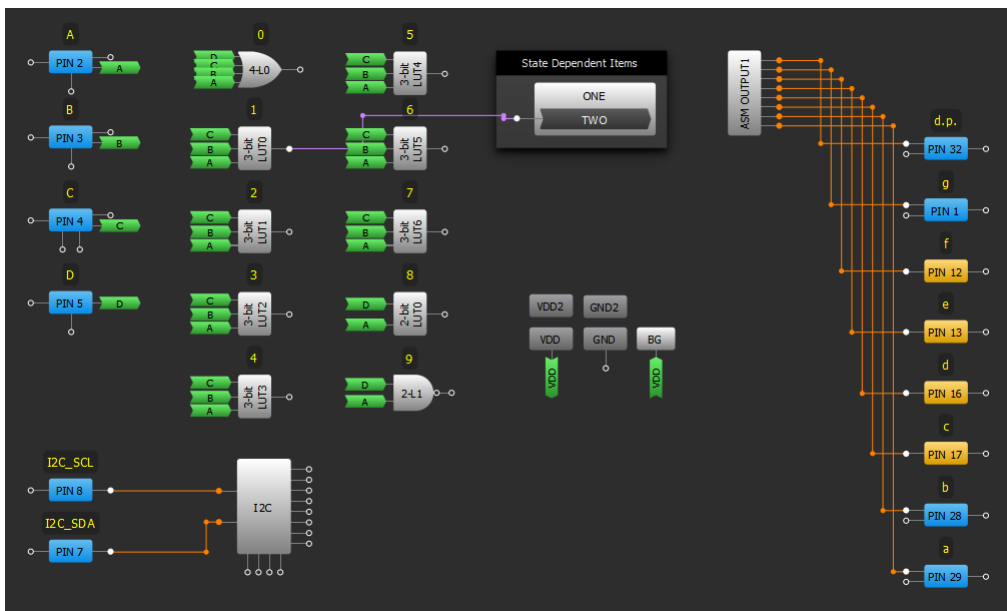

Figure 14: GreenPAK Design for CD4543

10 Conclusion

The Dialog GreenPAK SLG46880 is a versatile device with many internal resources, which allow a designer to create much more complicated systems than the ones we could make with a few ICs in the CD40XX family. Thanks to its small size and considerable flexibility, including a GreenPAK device in your project may help you reduce both the size and the complexity of your PCB.

Revision History

Revision	Date	Description
1.0	15-Mar-2018	Initial Version

Status Definitions

Status	Definition
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APPROVED or unmarked	The content of this document has been approved for publication.

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