Part III: Sequential Circuit Study Report

JB Ruutelmann, Samson Fortnite George[*a], Vitaly Slabada*[b]

ABSTRACT
In this paper, we investigate the efficacy of a given test vector set on a sequential circuit vs. a combinational circuit. While a direct comparison cannot be made due to the nature of these circuits, every effort is made to reduce their differences (same number of gates, same input/output lines).

KEYWORDS
List Eight to Ten Capitalized Keywords Separated by Semicolons; Do Not Use Period at The End

1 INTRODUCTION

The goal of this experiment is to examine the relationship between the fault coverage of a set of test vectors when applied to both sequential and combinational circuits.

Hypothesis:
There is a correlation between the fault coverage provided by the same test vector when it is applied to sufficiently similar combinational and sequential circuits. "Sufficiently similar" is defined as having the same number of gates, inputs and outputs.

We predict that, given the same test vector set applied to two sufficiently similar sequential and combinational circuits, there will be more faults detected from the sequential circuit. This is due to the "shifting" nature of the circuit, and any D or D' that is produced will be more easily "shifted" to the output.

2 METHODS AND PROCEDURES

Experiment Design:
Four test circuits were designed, each in two flavors - sequential and combinational (eight in total). The test vectors 00, 01, 11 were fed to the two-input circuits, and the test vectors 000, 001, 111 were fed to the three-input circuits. The detection rate for the sequential and combinational (DFFs were removed and replaced with a wire) circuits were compared.

Inputs were applied constantly for five cycles.

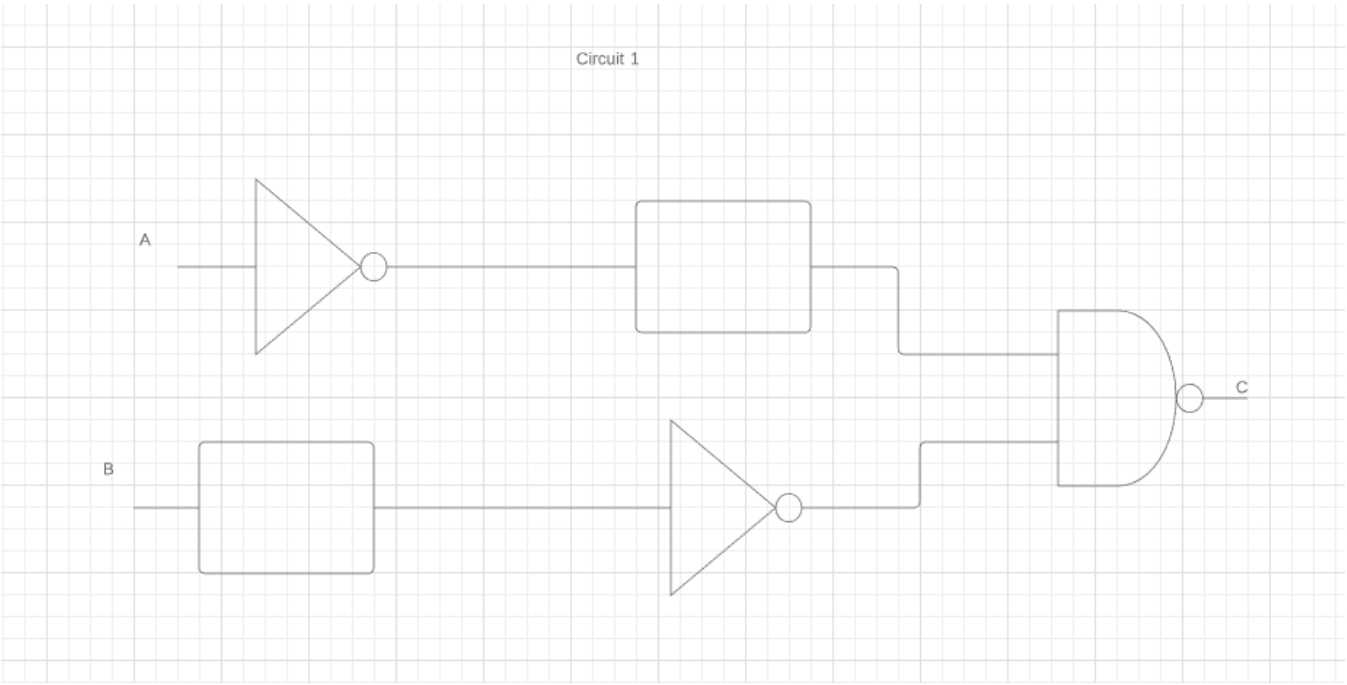

Figure 1. Circuit 1 contained two DFFs and two NOT gates

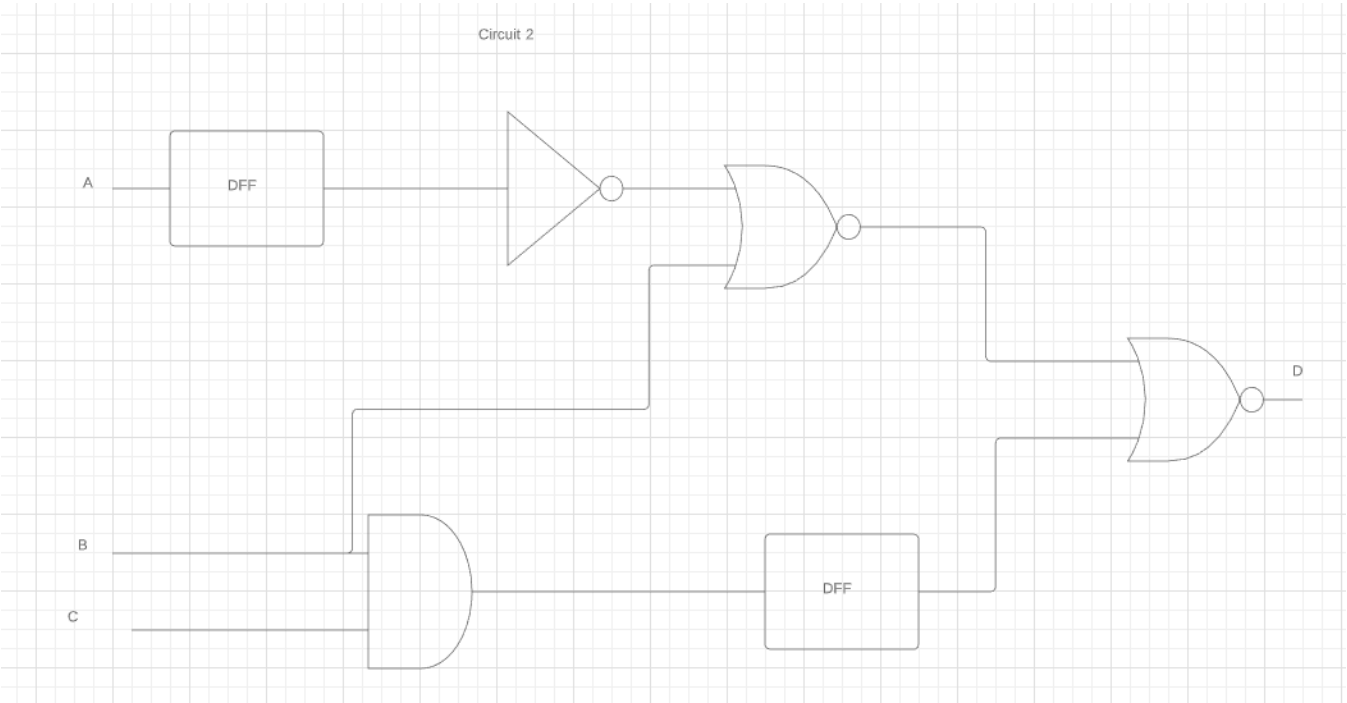

Figure 2. Circuit 2 contained a fan-out, three inputs and three DFFst

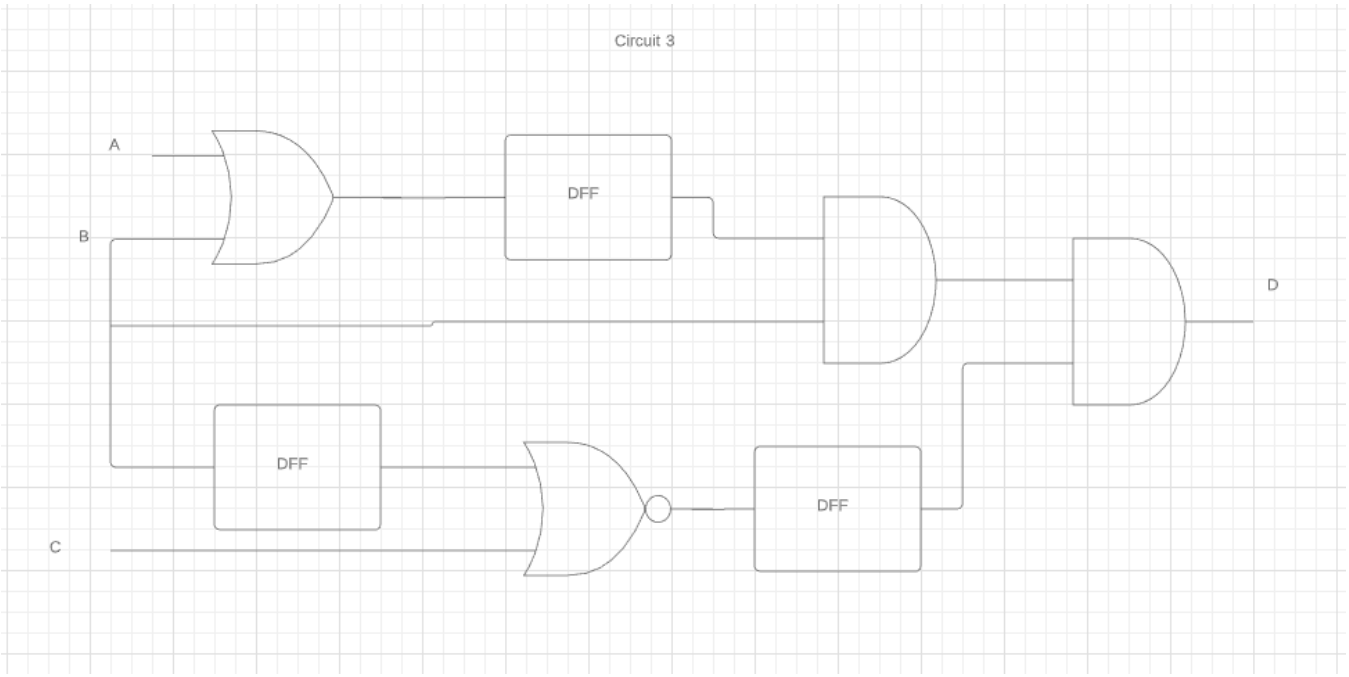

Figure 3. Circuit 4 was a "chain" design

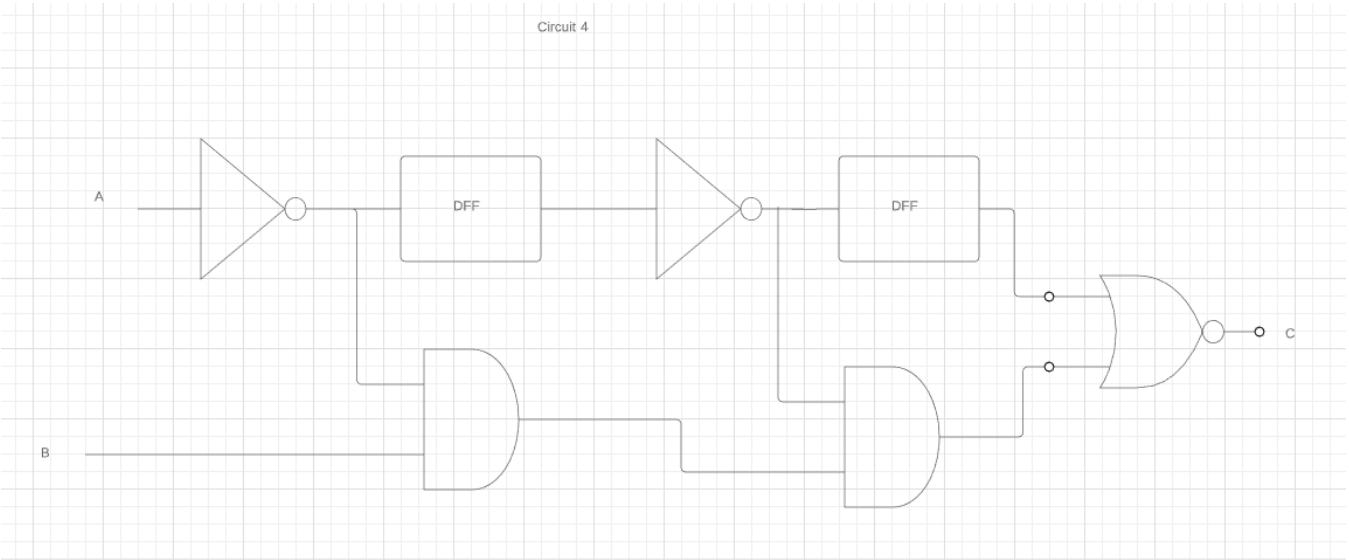

Figure 4. Circuit 4 contained two DFFs and two NOT gates

3 RESULTS

3.1 *Summary*

Our hypothesis was surprisingly accurate - error detection appears remarkably easier for sequential circuits than for combinational circuits. For every circuit, error detection in sequential circuits was better or the same as combinational circuits. For three circuits, the fault detection rate was double or more.

3.2 *Graphical representation of the data*

Circuit 1	Combinational				Sequential		
	00	01	11		00	01	11
A-SA-1	yes	x	x		x	yes (cycle 2)	yes (cycle 2)
A-SA-0	x	x	x		yes (cycle 2)	x	yes (cycle 2)
-	-	-	-	-	-	-	-
Circuit 2	Combinational				Sequential		
	000	001	111		000	001	111
A-SA-1	yes	yes	x		x	yes (cycle 2)	yes (cycle 1)
A-SA-0	x	x	x		yes (cycle 2)	x	yes (cycle 1)
-	-	-	-	-	-	-	-
Circuit 3	Combinational				Sequential		
	000	001	111		000	001	111
A-SA-1	x	x	x		yes (cycle 1)	yes (cycle 1)	yes (cycle 3)
A-SA-0	x	x	x		yes (cycle 1)	yes (cycle 1)	yes (cycle 3)
-	-	-	-	-	-	-	-
Circuit 4	Combinational				Sequential		
	00	01	11		00	01	11
A-SA-1	yes	yes	x		x	yes (cycle 3)	yes (cycle 3)
A-SA-0	x	x	yes		yes (cycle 3)	x	x

Figure 5. Table of Results

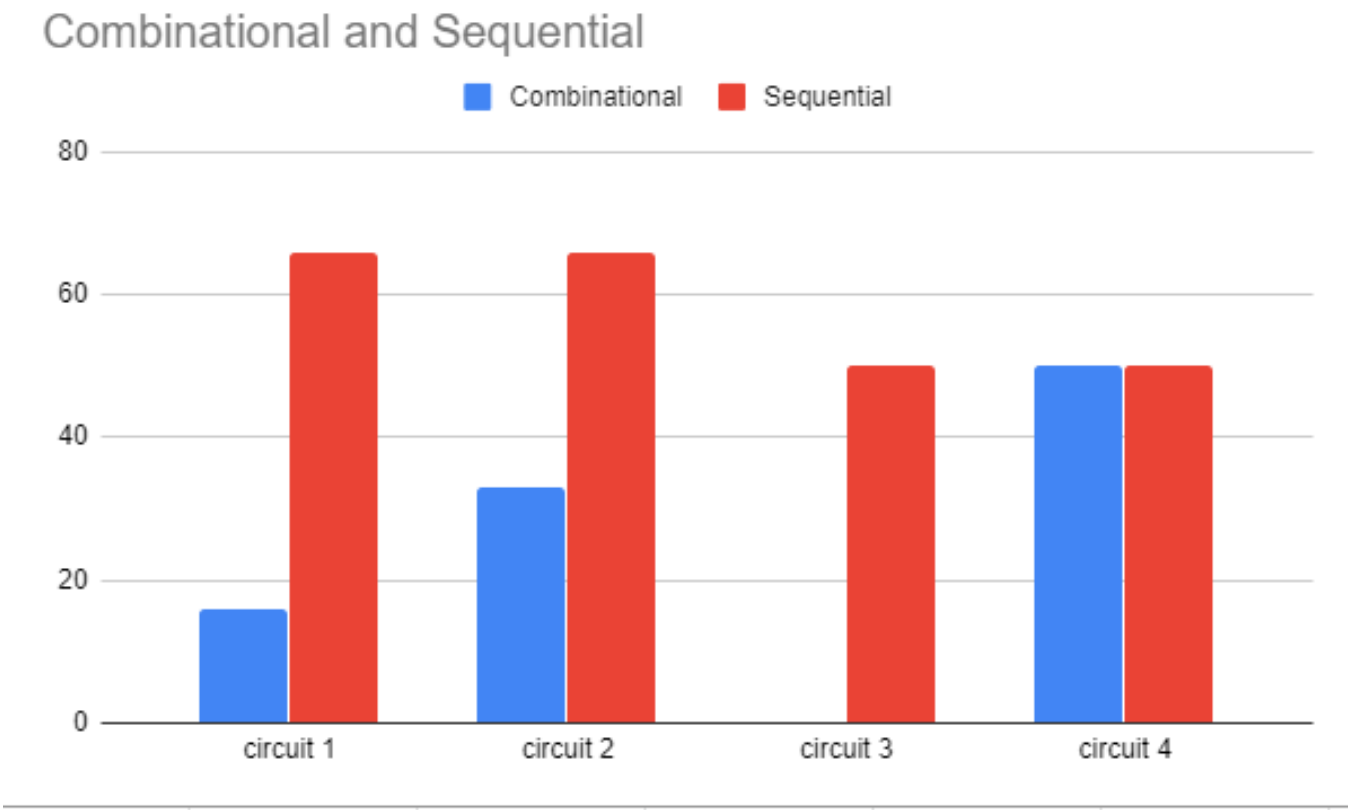

Figure 6. Comparison of fault detection, sequential vs combinational circuits

4 DISCUSSION

4.1 *Analysis*

One possible reason for the comparative ease of fault detection using sequential circuits is because once a 'D' or 'D bar' is created, it is 'shifted' through the circuit. However, this is similar to what happens in a combinational circuit, except all at once.

Another possible reason is that the inputs are applied over five cycles, and any cancellations of the D or D bar are given a 'second chance' on the next round, with possibly different inputs at the gates that have filtered through from previously. Looking at the raw data, most error detection occurs after the first cycle.

CONCLUSIONS

Our hypothesis was correct; fault detection for sequential circuits does indeed appear to be easier. However, it is likely due to the constant application of inputs over five cycles.