4.2 Using the circuit shown, compute the detection probabilities for each of the following faults:

a. $e/0$

b. $e/1$

c. $c/0$

Recall that the detection probability is $d_f = \frac{T_f}{2^n}$, where $T_f$ is the set of vectors that can detect fault $f$, and $n$ is the number of inputs in the circuit. In this circuit, we have 3 inputs, so there are a total of 8 possible vectors.

(a) For $e/0$, two vectors, $abc = \{011, 111\}$ can detect it. Thus $d_f = 0.25$

(b) For $e/1$, one vector, $abc = 010$ can detect it. Thus $d_f = 0.125$

(c) For $c/0$, two vectors, $abc = \{011, 101\}$ can detect it, Thus $d_f = 0.25$

4.3 Using the circuit shown, compute the set of all vectors that can detect each of the following faults using the Boolean difference.

a. $e/0$

b. $e/1$

c. $c/0$

(a) The set of vectors that can detect $e/0$ is

$$
(e = 1) \cdot \frac{d_e}{d_e} = e \cdot (z \cdot (e = 0) \oplus z(e = 1))
$$

$$
= e \cdot (g \oplus (g + b))
$$

$$
= e \cdot \left( g \cdot g + b + \overline{g} \cdot (g + b) \right)
$$

$$
= e \cdot \overline{g} \cdot b
$$

$$
= e \cdot \overline{ac} \cdot b
$$

$$
= e \cdot (a + c) \cdot b
$$

$$
= bc + \overline{abc}
$$

$$
= bc
$$

Thus, the set of vectors is $\{011, 111\}$.

(b) The set of vectors that can detect $e/1$ is
\[
\frac{d_z}{de} = e \cdot (z \cdot (e = 0) \oplus z(e = 1))
\]
\[
= e \cdot (g \oplus (g + b))
\]
\[
= e \cdot (g \cdot g + b + \overline{g} \cdot (g + b))
\]
\[
= e \cdot \overline{g} \cdot b
\]
\[
= e \cdot ac \cdot b
\]
\[
= \overline{e} \cdot (a + c) \cdot b
\]
\[
= bce + abe
\]
\[
= abc
\]
Thus, the set of vectors is \{01\}.

(c) The set of vectors that can detect c/0 is
\[
(c = 1) \cdot \frac{d_z}{dc} = e \cdot (z \cdot (c = 0) \oplus z(c = 1))
\]
\[
= c \cdot (a \oplus b)
\]
\[
= c \cdot (a \cdot \overline{b} + \overline{a} \cdot b)
\]
\[
= \overline{abc} + abe
\]
Thus, the set of vectors is \{01, 10\}.

4.4 Using the circuit shown, compute the set of all vectors that can detect each of the following faults using the Boolean difference:

a. a/1
b. d/1
c. g/1

(a) The set of vectors that can detect a/1 is
\[
(a = 0) \cdot \frac{d_i}{da} = \overline{a} \cdot (i \cdot (a = 0) \oplus i(a = 1))
\]
\[
= \overline{a} \cdot (0 \oplus b)
\]
\[
= \overline{ab}
\]
Thus, the set of vectors is \{01\}.

(b) The set of vectors that can detect d/1 is
\[
(d = 0) \cdot \frac{d}{dd} = \overline{d} \cdot (i \cdot (d = 0) \oplus i(d = 1))
\]
\[
= \overline{d} \cdot (0 \oplus ab)
\]
\[
= \overline{d} \cdot ab
\]

But it is impossible to set \(a=1\) and \(d=0\) simultaneously. Thus, the set of vectors is \(\emptyset\).

(c) The set of vectors that can detect \(g/1\) is
\[
(g = 0) \cdot \frac{d}{dg} = \overline{g} \cdot (i \cdot (g = 0) \oplus i(g = 1))
\]
\[
= \overline{g} \cdot (0 \oplus ab)
\]
\[
= \overline{g} \cdot ab
\]
\[
= \overline{ab} \cdot ab
\]
\[
= 0
\]

Thus, the set of vectors is \(\emptyset\).

4.7 Construct the table for the XNOR operation for the 5-valued logic similar to Tables 4.1, 4.2, and 4.3.

<table>
<thead>
<tr>
<th>XNOR (X)</th>
<th>(0)</th>
<th>(1)</th>
<th>(D)</th>
<th>(\overline{D})</th>
<th>(X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0)</td>
<td>(1)</td>
<td>(0)</td>
<td>(\overline{D})</td>
<td>(D)</td>
<td>(X)</td>
</tr>
<tr>
<td>(1)</td>
<td>(0)</td>
<td>(1)</td>
<td>(D)</td>
<td>(\overline{D})</td>
<td>(X)</td>
</tr>
<tr>
<td>(D)</td>
<td>(\overline{D})</td>
<td>(D)</td>
<td>(1)</td>
<td>(0)</td>
<td>(X)</td>
</tr>
<tr>
<td>(\overline{D})</td>
<td>(D)</td>
<td>(\overline{D})</td>
<td>(0)</td>
<td>(1)</td>
<td>(X)</td>
</tr>
<tr>
<td>(x)</td>
<td>(X)</td>
<td>(X)</td>
<td>(X)</td>
<td>(X)</td>
<td>(X)</td>
</tr>
</tbody>
</table>

4.8 Using the circuit shown, use the D-algorithm to compute a vector for the fault \(b/1\). Repeat for the fault \(e/0\).

Initially, we place a \(\overline{D}\) on \(b\). The D-frontier at this time includes \(\{d, e\}\). Next, we pick a D-frontier to propagate the fault effect across. Suppose we pick \(d\). Then, the decision \(a=0\) is made. At this time, the D-frontier becomes \(\{x, e\}\). We pick the D-frontier that is closest to a PO. Thus, we pick \(x\). The next decision is \(e1=0\). This decision implies \(y=1\) and \(z=D\). In other words, the fault-effect has been propagated all the way to the PO. The J-frontier consists of \(\{e1=0, b=\overline{D}\}\). To justify \(e1=0\), \(c=0\) is sufficient. Justifying
b=\overline{D} is likewise straightforward, simply by setting b=0. Thus the vector \text{abc}=000 detects the target fault b/1.

A similar decision process is made for the target fault e/0. However, in this case, one would conclude that the fault is untestable.

4.11 Using the circuit shown and PODEM, compute the vector that can detect the fault f/0. Note that even though the circuit is sequential, it can be viewed as a combinational circuit because the D flip-flop does not have an explicit feedback.

![Circuit Diagram]

<table>
<thead>
<tr>
<th>Objective</th>
<th>Backtrace</th>
<th>Assignment</th>
<th>Implications</th>
<th>Decision Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>(f, 1)</td>
<td>(d, 1), (e, 1), (a, 1)</td>
<td>a = 1</td>
<td>d = 1</td>
<td>a = 1</td>
</tr>
<tr>
<td>(f, 1)</td>
<td>(e, 1), (c, 1)</td>
<td>c = 1</td>
<td>e = 1, f = D, g = D</td>
<td>a = 1, c = 1</td>
</tr>
<tr>
<td>(h, 0)</td>
<td>(h, 0)</td>
<td>h = 0</td>
<td>j = D, w = D'</td>
<td>a = 1, c = 1, h = 0</td>
</tr>
<tr>
<td>(x, 1)</td>
<td>(x, 1), (k, 1), (i, 1)</td>
<td>i = 1</td>
<td>k = 1, x = D, no path</td>
<td>a = 1, c = 1, h = 0, i = 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i = 0</td>
<td>k = D, x = D, no path</td>
<td>a = 1, c = 1, h = 0, i = 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>h = 1</td>
<td>j = 1, w = 0, x = 0, no path</td>
<td>a = 1, c = 1, h = 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c = 0</td>
<td>f = 0, no excitation</td>
<td>a = 1, c = 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a = 0</td>
<td>w = 1</td>
<td>a = 0</td>
</tr>
<tr>
<td>(f, 1)</td>
<td>(d, 1), (b, 1)</td>
<td>b = 1</td>
<td>d = 1</td>
<td>a = 0, b = 1</td>
</tr>
<tr>
<td>(f, 1)</td>
<td>(e, 1), (c, 1)</td>
<td>c = 1</td>
<td>f = D, g = D</td>
<td>a = 0, b = 1, c = 1</td>
</tr>
<tr>
<td>(h, 0)</td>
<td>(h, 0)</td>
<td>h = 0</td>
<td>j = D</td>
<td>a = 0, b = 1, c = 1, h = 0</td>
</tr>
<tr>
<td>(k, 1)</td>
<td>(i, 1)</td>
<td>i = 1</td>
<td>k = 1, y = 0, z = 0, no path</td>
<td>a = 0, b = 1, c = 1, h = 0, i = 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i = 0</td>
<td>k = D, x = D, y = D', no path</td>
<td>a = 0, b = 1, c = 1, h = 0, i = 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>h = 1</td>
<td>j = 1</td>
<td>a = 0, b = 1, c = 1, h = 1</td>
</tr>
<tr>
<td>(i, 0)</td>
<td>(i, 0)</td>
<td>i = 0</td>
<td>k = D, y = D', x = D, no path</td>
<td>a = 0, b = 1, c = 1, h = 1, i = 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i = 1</td>
<td>k = 1, y = 0, z = 0, no path</td>
<td>a = 0, b = 1, c = 1, h = 1, i = 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c = 0</td>
<td>e = 0, f = 0, no excitation</td>
<td>a = 0, b = 1, c = 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b = 0</td>
<td>d = 0, f = 0, no excitation</td>
<td>a = 0, b = 0</td>
</tr>
</tbody>
</table>

No further options available, fault redundant