Automatic Test Pattern Generation for Stuck-at Faults.

Given: 1. A gate-level ckt model = Golden model = fault-free circuit = O

Do: 2. Pick a net in C. Assume a net \( x_i \in C \) is stuck-at-0. Derive a test for \( x_i \) stuck-at 0. Denoted \( T x_i/0 \).

Test: A set of vectors at primary inputs that distinguishes the faulty and fault-free \( O \) under the presence of \( x_i/0 \).

3) Repeat 2 for \( x_i/1 \): Find \( T x_i/1 \)

4) Repeat for all nets.

Test set = \( \bigcup \{ T x_i/0, T x_i/1 \big| x_i \in C \} \)

Test S-a-f on Primary Inputs.

\[ \text{Diagram of circuit} \]

Test b/
To test b/1:

i) Fault Activation: - or excitation
   Apply $b = 0$, the value complement of stuck value

ii) Fault propagation: Apply values on the
   Side-inputs (other inputs) such that
   the fault-effect propagates to P.O.

iii) For this, you need non-controlling values
    on the side-inputs of the gates on the
    sensitized path.

\[ \text{non-controlling value} \]
\[ 0 = \text{controlling value} \]

\[ \text{XORs} \rightarrow \text{no controlling values.} \]
iv) Path sensitization.
   - Single path sensitization \( \forall \).
   - Multi \( \forall \).

\[ \begin{align*}
q &= 1 \\
 b &= 0, \\
 c &= 0
\end{align*} \]

**Single path sensitization.**

\[ b \rightarrow g \rightarrow z. \]

1. \( b=0 \):
   - Fault-free

2. \( q=1 = \text{non-controlling value.} \)
   \[ g = \frac{1}{0} \]
   \[ h = 0, \quad z = 1/0 = \text{faulty = 0} \]

3. Can we get \( h=0 \)? Justification needed.
   \[ c= ? \text{ so that } h=0? \]
   Not possible to get \( h=0 \).

4. Try a different single path.
   \[ b \rightarrow h \rightarrow z. \]
   \[ c=1, \quad h = \frac{1}{0}, \quad g = 0, \quad z = \frac{1}{0}. \]

Justification not possible.

Single path sensitization fails.
Try Multi-path sensitization.

\[ a = 1 \rightarrow Do \rightarrow y_0 \]
\[ b = 0 \rightarrow \]
\[ c = 1 \]
\[ y_0 \rightarrow \]
\[ \text{success!} \]

\[ T_{b/4} = \{ a = 1, b = 0, c = 1 \} \]

IF no fault exists, \( Z = 1 \) detected.
IF fault exists, \( Z = 0 \).

Sometimes: Single path sensitization works.
Sometimes: Multi-path works.
Sometimes: Both may work.
Other times: None may work.
Untestable fault.

Test on PIs: \( T_{x/1} = \frac{\partial Z}{\partial x} \)
Activation \( \rightarrow \) Propagation

Prove it: remember Boolean difference.
Fault Free $Z = \frac{T_x}{2}$
Faulty $Z_f = Z(x=1)$

Miter $Z \oplus Z_f (x=1) = T_{xy}$

Shannon's Expansion:

$Z = xZ_x + \overline{x}Z_{\overline{x}}$

$= xZ_x \oplus \overline{x}Z_{\overline{x}}$

$T_{xy} = xZ_x \oplus \overline{x}Z_{\overline{x}} \oplus Z(x=1)$

$= xZ_x \oplus \overline{x}Z_{\overline{x}} \oplus Z_x$

$= xZ_x \oplus Z_x \oplus \overline{x}Z_{\overline{x}}$

$= Z_x (x + 1) \oplus \overline{x}Z_{\overline{x}}$

$= \overline{x}Z_x \oplus \overline{x}Z_{\overline{x}}$

$= \overline{x} \left[ Z_x + Z_{\overline{x}} \right] = \overline{x} \frac{\partial Z}{\partial x}$

$T_{xy} = x \cdot \frac{\partial Z}{\partial x}$

Trick: Shannon's OR = also XOR
\[ a \rightarrow b \rightarrow c \rightarrow z = \overline{(a \cdot b)} + (c \overline{b}) \]

\[ \frac{\partial z}{\partial b} = z_b \oplus \overline{z_b} \]

\[ = \left[ \overline{a \cdot 1} + (1 \cdot 0) \right] \oplus \overline{0 + 0} \]

\[ = \left[ \overline{a + 0} \right] \oplus 1 \]

\[ = \left[ \overline{a + c} \right] = a \cdot c. \]

\[ T_{by} = b = 0, a = 1, c = 1 \]

\[ T_{by_0} = b = 1, a = 1, c = 1 \]

Fanout stems versus Fanout branches.

Fanout re-converges to \( z = \) re-convergent fanouts.

Stem faults ≠ branch faults.
See slide #19 Tre

\[ a \quad \xrightarrow{\text{e}_1} \quad \text{Do} \quad \xrightarrow{\text{e}_1} \quad \text{Tre} \]

\[ b=0 \quad \xrightarrow{\text{e}_1} \quad \text{Do} \]

\[ b=0, \quad \boxed{\text{e}=1} \quad z=1 \]

\[ \Rightarrow d=0 \Rightarrow z=1 \quad z=1 \]

No Test \(\Rightarrow\) Redundancy.

Redundancy can be detected.

\[ e_1 \Rightarrow e=1 \text{ has no effect on } z. \]

Put \( e=1 \) & simplify.

\[ a \quad \xrightarrow{\text{e}_1} \quad \text{Do} \quad \xrightarrow{\text{e}_1} \quad \text{Tre} \]

\[ b \quad \xrightarrow{\text{Do}} \quad \text{Do} \]

\[ c \quad \xrightarrow{\text{Do}} \quad \text{Do} \]