VLSI Testing
積體電路測試

Logic Built-In Self Test (BIST)
*Part 2: ORA, BIST Architecture**

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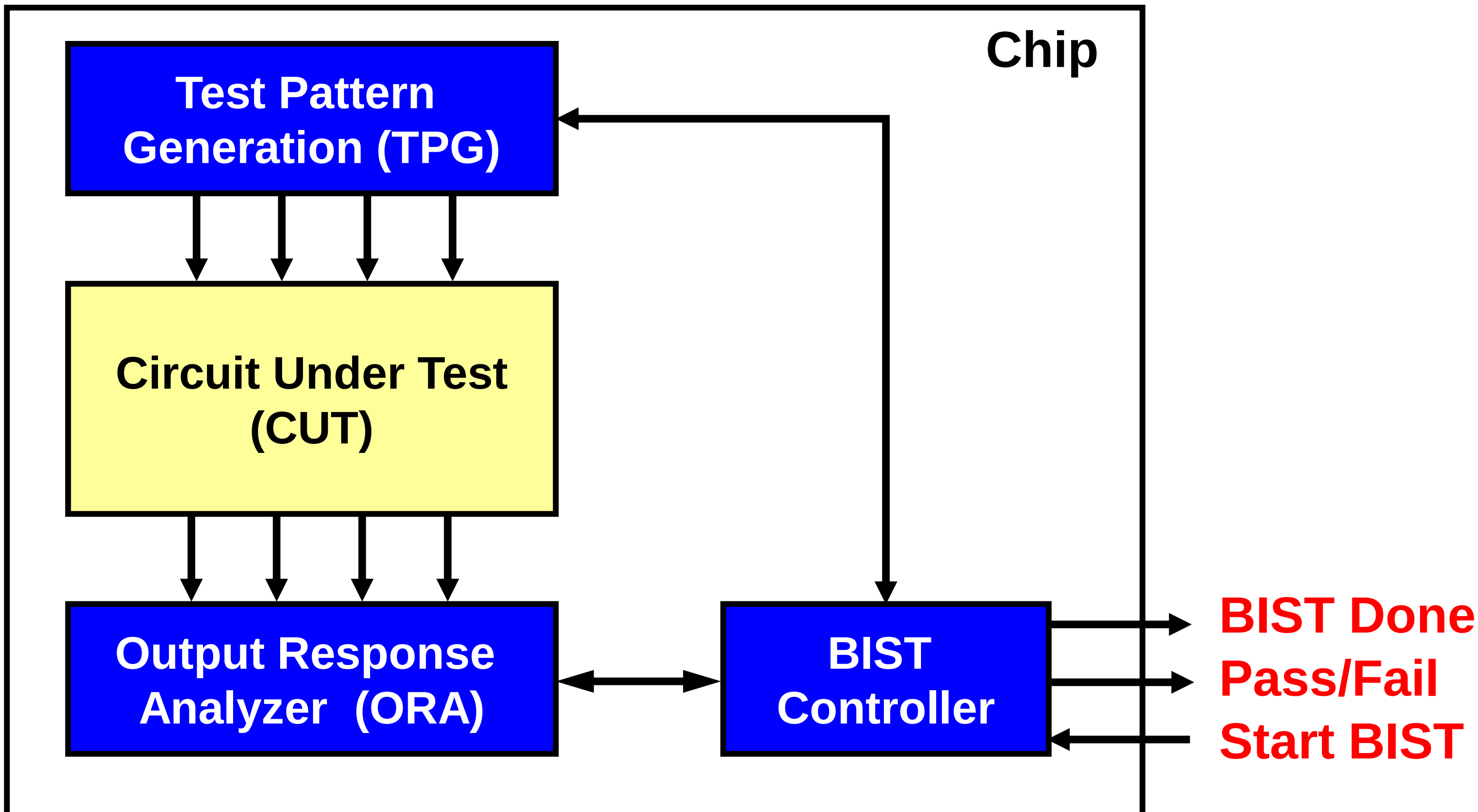
* Some pictures are courtesy of Prof. Shi-yu Huang, NTHU

Architecture of BIST (Review)

- **Three components:** ***BIST Controller, TPG, ORA***
- **Three I/O Pins:** ***Start BIST, BIST Done, Pass/Fail***



Why Am I Learning This?

- **Output Response Analyzer**
  - **Observe CUT output responses on chip**
  - **Very small area but correct Pass/Fail decision**

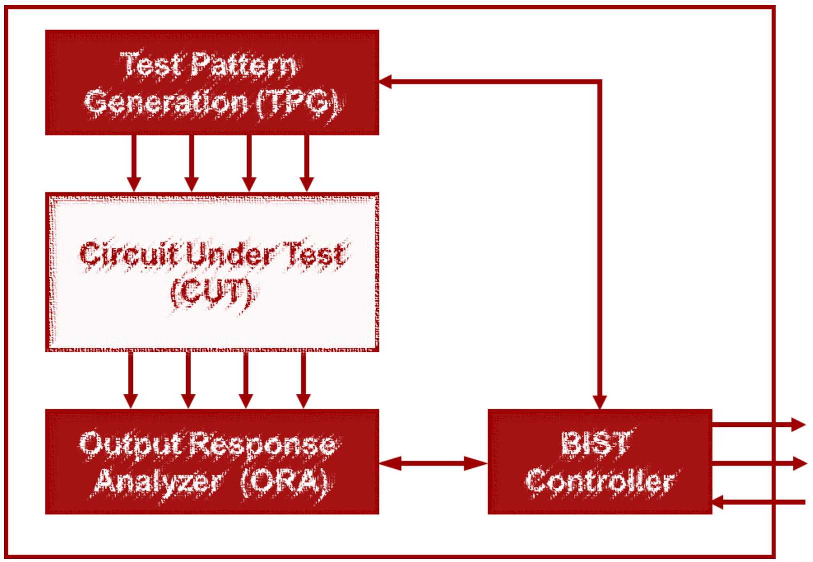
"What the superior man seeks is in himself; what the small man seeks is in others."

君子求諸己，小人求諸人

(Confucius)

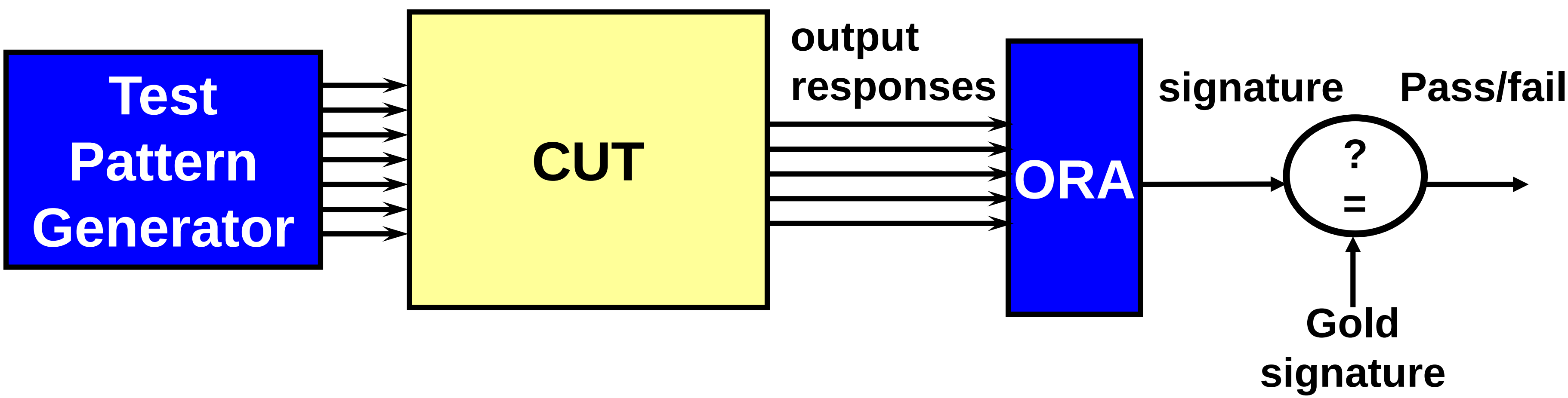
BIST Part 2

- Part 1
  - Introduction
  - Test Pattern Generation
- Part 2
  - Output Response Analysis
  - BIST Architecture
  - Issues with BIST
  - Conclusions



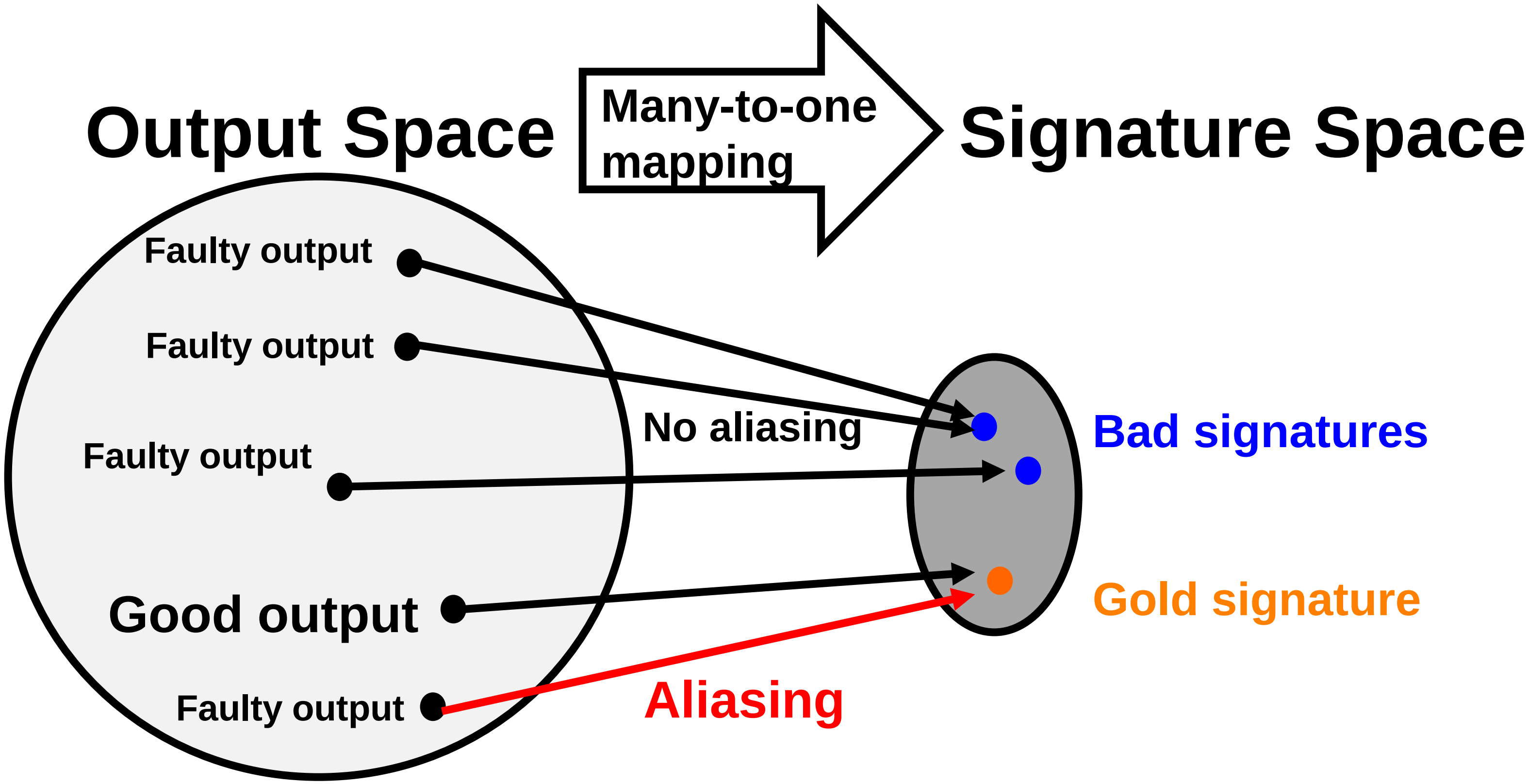
Output Response Analyzer

- **What is ORA?**
  - **Compress CUT output responses into a small *signature***
  - **Compare signature with *gold signature* to determine pass or fail**
  - **ORA also called *signature analyzer***
- **What is good ORA? (very difficult to meet all requirements)**
  - **1. Signature as small as possible**
  - **2. Correct Pass/Fail decision (*i.e.* low *aliasing*, see next slide)**
  - **3. Small area**
  - **4. Diagnosis support**



Aliasing

- *Aliasing* occurs when
  - $\text{signature}_{\text{faulty output}} = \text{signature}_{\text{good output}}$ (*gold signature*)
- Aliasing → Fault coverage loss → *Test escapes*
  - Defective circuits pass tests (Very bad!)



Probability of Aliasing

- **Aliasing depends on many factors:**
  - **CUT, faults, test pattern, ORA structure**
  - **Exact analysis of aliasing difficult**
  - **Just probability analysis is good enough**
- ***Probability of Aliasing (PAL)***

$$PAL = \frac{number\ of\ \ faulty\ \ outputs\ \ that\ \ generate\ gold\ \ signature}{total\ number\ of\ \ faulty\ outputs}$$

  - **PAL between 0 and 1. Lower is better.**

Good ORA Requires Low PAL

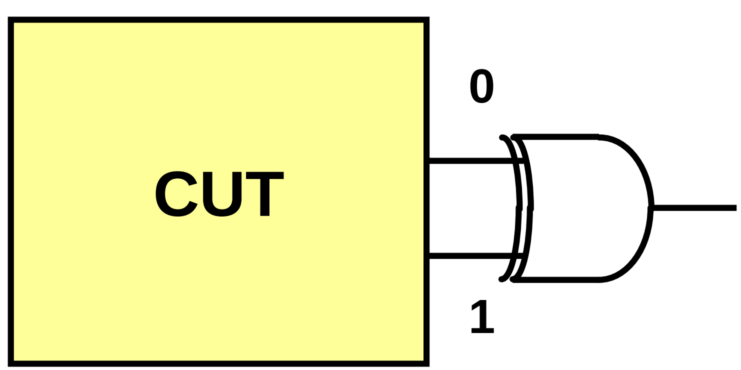
Quiz

Q1: We use OR gate as ORA. Suppose good output is ’01’, what is gold signature?
ANS:

Q2: What is PAL of this ORA? Suppose ‘00, 01 10, 11’ equally likely

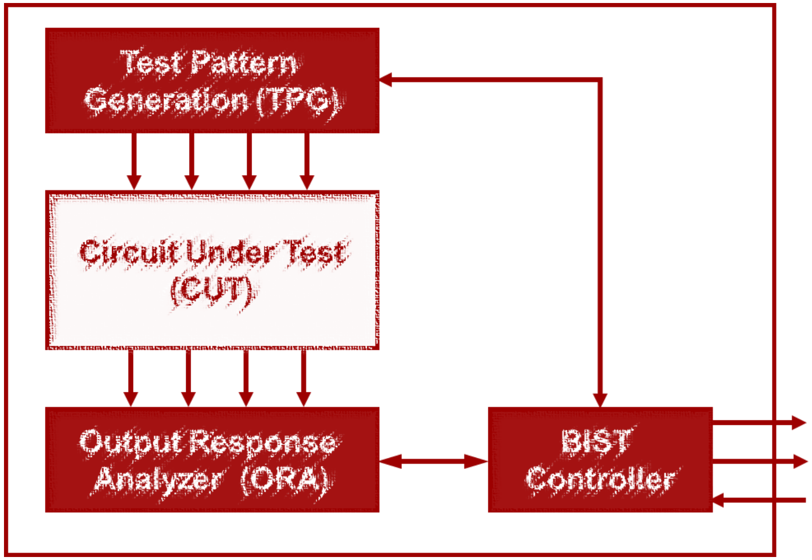
$$\boxed{PAL = \frac{number\ of\ \ faulty\ \ outputs\ \ that\ \ generate\ gold\ \ signature}{total\ number\ of\ \ faulty\ outputs}}$$

ANS:



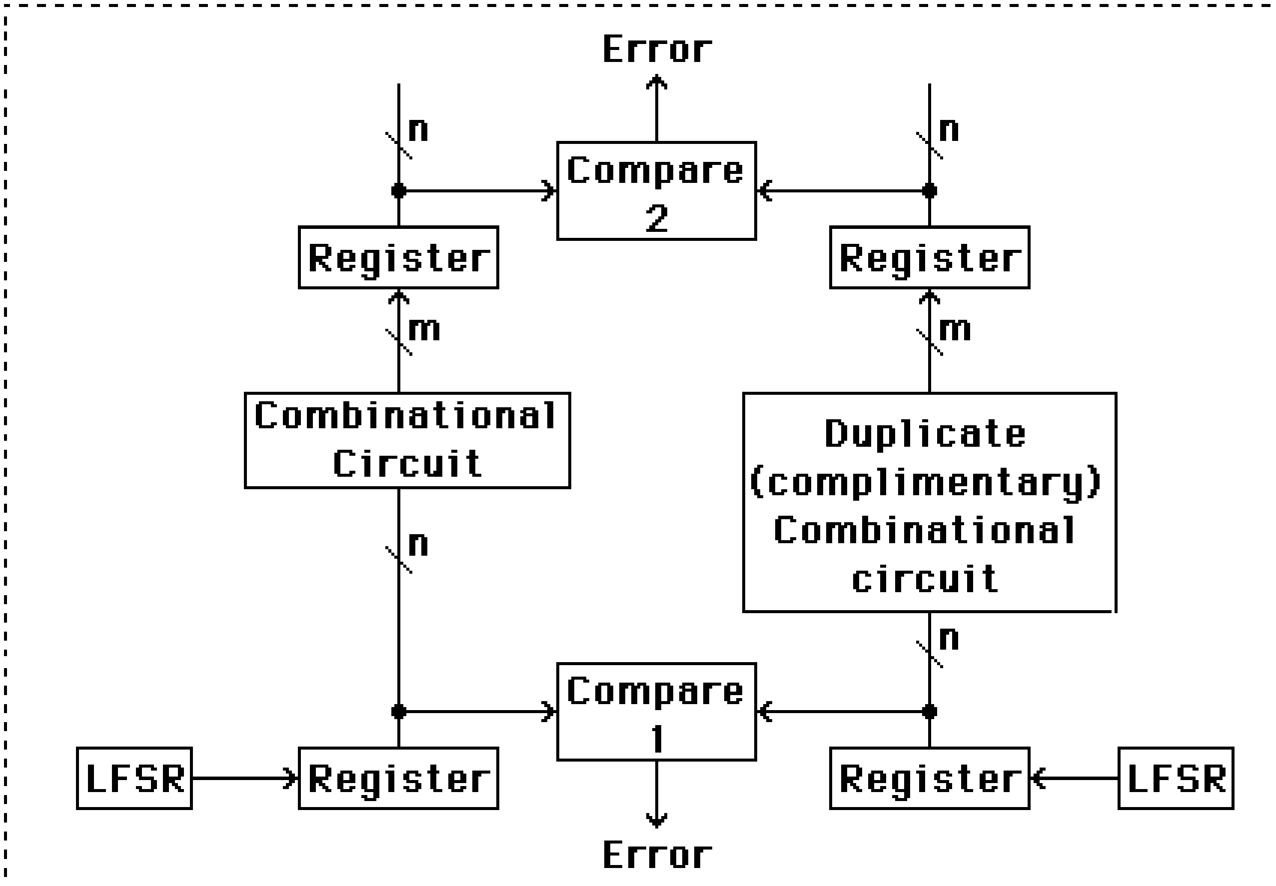
BIST Part 2

- Output Response Analysis
  - Simple ORA
    - Duplication, Reverse operation
    - Checksum (aka. Parity Checker)
    - Ones counter
    - Transition counter
  - LFSR-based
- BIST Architecture
- Issues with BIST
- Conclusions



Duplication

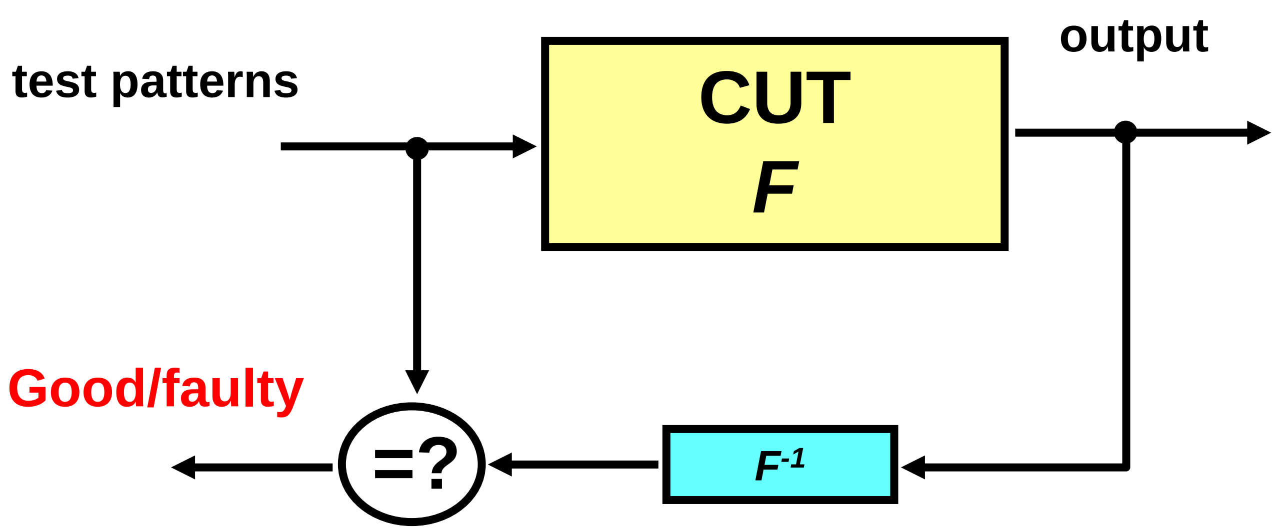
- Advantage: low aliasing; good for on-line BIST
- Disadvantages: too big in area



Courtesy of McCluskey, Stanford University

Reverse Operation

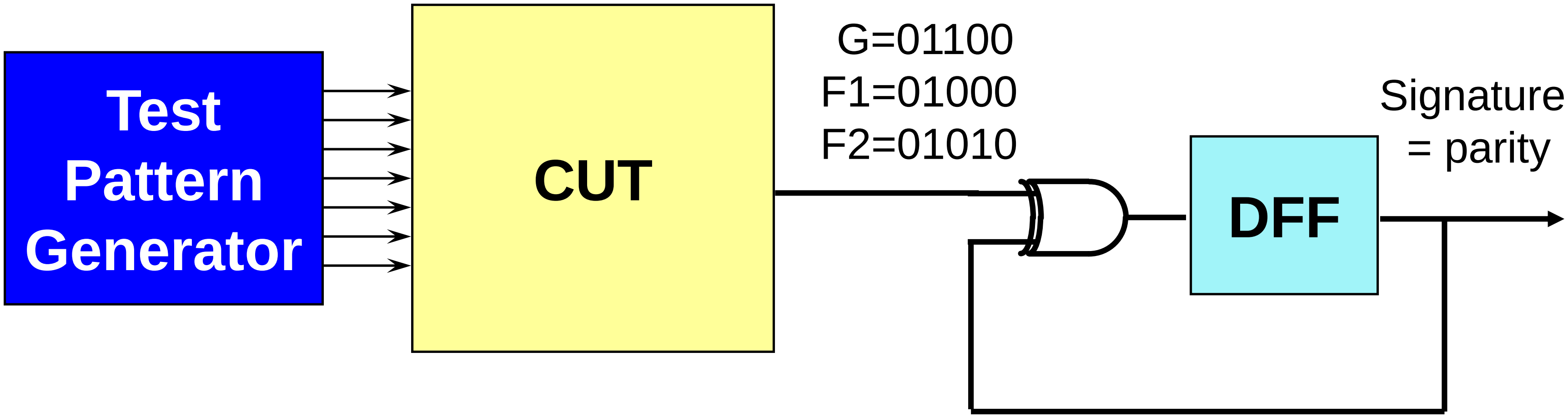
- **Advantages**
  - **Applicable to both on-line and off-line BIST**
  - **Low aliasing**
- **Disadvantages**
  - **Not generally applicable to all CUT**



F^{-1} is reverse operation of F

Parity Checker

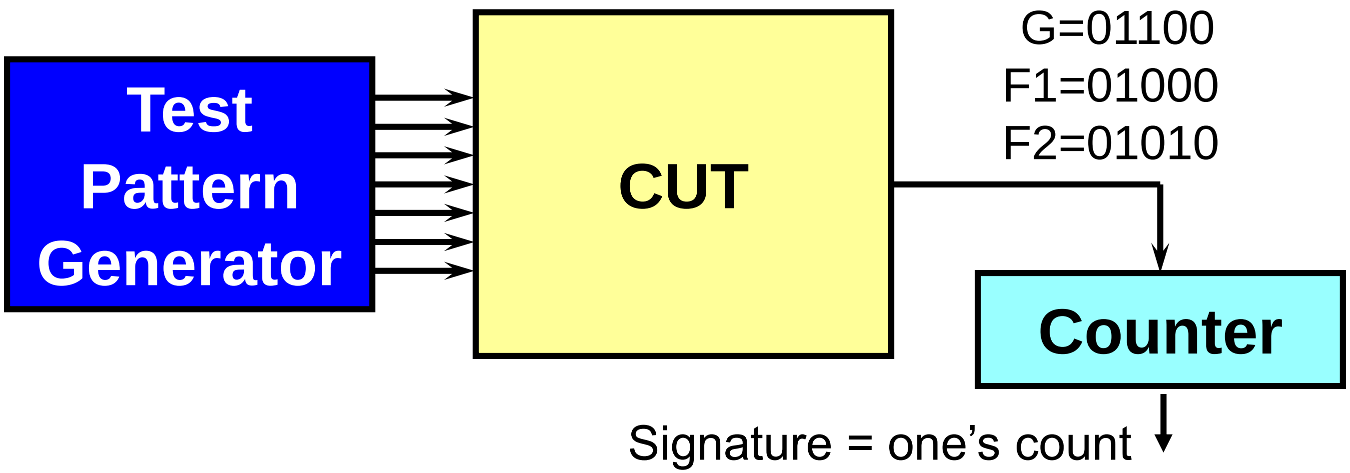
- **Signature = Inversion parity of CUT output**
  - **Odd or even**
- **Example (initially DFF=0)**
  - **Good CUT output = 01100 → 0 gold signature**
  - **Faulty CUT1 output = 01000 → 1 detected, no aliasing**
  - **Faulty CUT2 output = 01010 → 0 not detected, aliasing**



$$PAL = \frac{number\ of\ \ faulty\ \ outputs\ \ that\ \ generate\ gold\ signature}{total\ number\ of\ \ faulty\ outputs} = \frac{16-1}{2^5-1} = \frac{15}{31}$$

Ones Counter

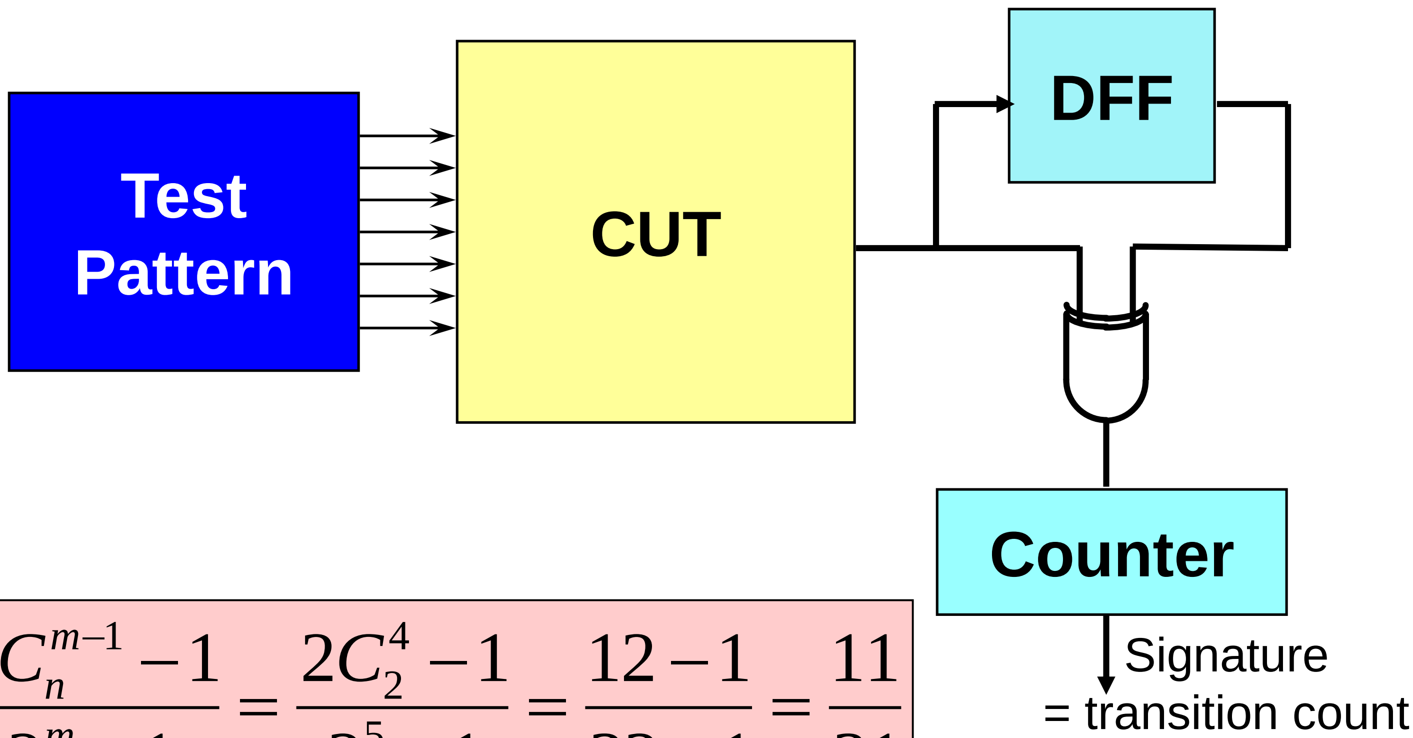
- **Signature = number of ones**
- **Example: sequence length=5=*m*; signature=2=*n*;**
  - **Good CUT output = 01100 → 2 gold signature**
  - **Faulty CUT1 output = 01000 → 1 detected, no aliasing**
  - **Faulty CUT2 output = 01010 → 2 not detected, aliasing**



$$PAL = \frac{C_n^m - 1}{2^m - 1} = \frac{C_2^5 - 1}{2^5 - 1} = \frac{10 - 1}{32 - 1} = \frac{9}{31}$$

Transition Counter

- Signature = number of transitions (0→1, 1→0)
- Example: sequence length=5=*m*; signature=2=*n*;
  - Good CUT output = 01100 → 2
  - Faulty CUT1 output = 01000 → 2 not detected, aliasing
  - Faulty CUT2 output = 01010 → 4 detected, no aliasing



$$PAL = \frac{2C_n^{m-1} - 1}{2^m - 1} = \frac{2C_2^4 - 1}{2^5 - 1} = \frac{12 - 1}{32 - 1} = \frac{11}{31}$$

Summary

- **Output Response Analyzer**
  - **Compress CUT output responses into signatures**
  - **Aliasing mean faulty outputs compressed into gold signature**
    - **induces test escape**
  - **Probability of aliasing (PAL)**

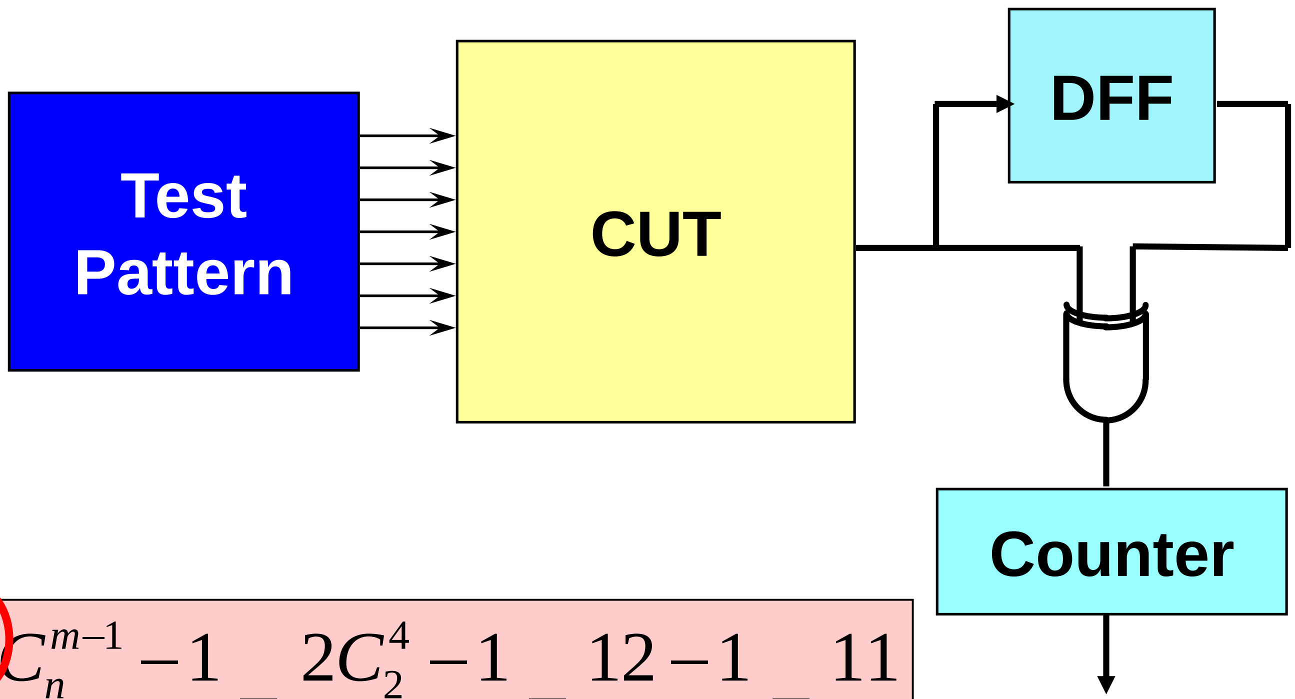
$$PAL = \frac{number\ of\ \ faulty\ \ outputs\ \ that\ \ generate\ gold\ \ signature}{total\ number\ of\ \ faulty\ outputs}$$

  - **Simple ORA**
    - **Duplication**
    - **Parity Checker**
    - **Ones counter**
    - **Transition counter**

These ORA not Good Enough

FFT: Transition Counter

- Q: Why factor of 2 in PAL?



$$PAL = \frac{2C_n^{m-1} - 1}{2^m - 1} = \frac{2C_2^4 - 1}{2^5 - 1} = \frac{12 - 1}{32 - 1} = \frac{11}{31}$$