Increasing the Comprehensibility of Oscillation based Built-In Self Test (OBIST) using Frequency to Fault Code Converter

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Abstract:
A new strategy to increase the comprehensibility of Oscillation based Built-In Self Test (OBIST) of either a SOC or part of a complex mixed-signal system is described. In the test mode, a circuit under test (CUT) is transformed to an oscillator providing a feedback to the CUT. The oscillation frequency is then converted to a corresponding fault code using a new concept of Point of Coincidence (POC).

Index Terms: *Frequency to fault code Converter, Built-in self test (BIST), Oscillation based Built-In Self Test (OBIST), Circuit under Test (CUT), Point of Coincidence (POC), mixed-signal test, fault detection, level crossing detector (LCD)*

I. INTRODUCTION

Increasing the integration density enables, production of complex analog and mixed-signal integrated systems, this in recent years have motivated system designers and test-engineers to shift their research interest direction towards this particular area of very high large-scale integrated circuits and systems to develop specifically their effective test strategies [1],[2]. Mixed-signal and analog integrated circuit fabrication process involves a series of steps, which in real world aren't perfect and results in imperfections. Such imperfections may lead to failures in the operation of the individual integrated circuits, more so in case mixed-signal and analog integrated circuits. This is why every integrated circuit must be rigorously tested before being shipped to their vendors or customers. Testing not just improves the overall quality of the final product, but also can be a strategy for validating design and the technology.

Development of new test method strategies and approaches represents an important task of testing complex embedded systems. Performing test part by part could be the proper and possible test approach in some applications. Such approach is based on dividing the complex system into small parts that can be easily tested separately [3], [4]. Almost every mixed-signal integrated system contains circuits such as operational amplifiers, filters, oscillators, PLLs etc. During the test mode, all these circuits can be transformed into an oscillator by connecting some additional circuitry i.e., a feedback network. If possible faults are indeed present in the Circuit under Test (CUT), this would cause a deviation in the oscillation parameters like amplitude of the oscillations, oscillation frequency and so on. Hence making it possible not just determine if the device is faulty or fault free, but also pin-point the exact location of the fault.

To make the OBIST model more comprehensible, robust and efficient, we propose Frequency to Fault Code converter; this is evaluated by comparing the oscillation frequency taken from a CUT with a reference frequency.

II. PROPOSED TEST STRATEGY

2.1. Building a CUT

Many techniques have been proposed in the literature for converting a CUT into an oscillator using appropriate circuitry. One way to design a sinusoidal oscillator from the CUT is to connect the output terminal of the device to be tested to the input terminal. It is important to check the circuit satisfies Barkhausen's Criterion [5]. For this experiment, we use a simple RC phase-shift oscillator as shown in Fig. 1.

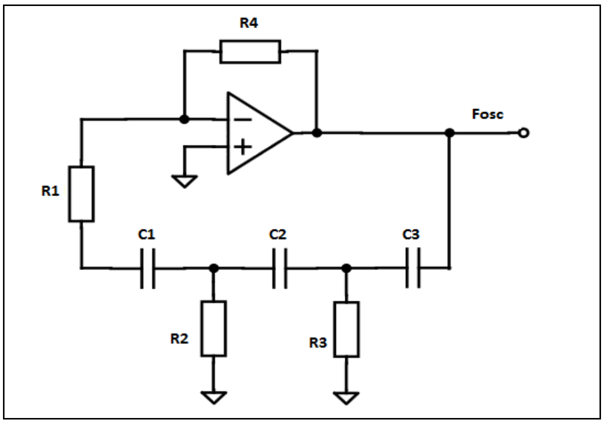

Fig.1 RC Phase-Shift oscillator

2.2. Reference Oscillator

To relate the frequency from CUT to a corresponding code, the experiment requires the use of a reference frequency. To achieve this, it is important to make use of a simple precise oscillator. This device makes use of a Schmitt oscillator, depicted in Fig. 2.

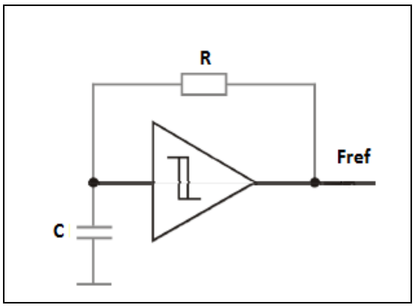

Fig. 2 A simple Schmitt oscillator

Reference frequency can be given by

$$Fref = \frac{1}{RC \, . \ln\left[\frac{(VDD - VSPH).\, VSPH}{(VDD - VSPL).VSPL}\right]} \qquad \ldots(1)$$

where, V_{DD} is the power supply voltage, V_{SPH} and V_{SPL} is the high and the low threshold voltage value of Schmitt trigger, respectively.

2.3. Test procedure

The output signals from the CUT and reference oscillator is passed through level-crossing detectors (LCD) and digital pulse for each of the signals is obtained. These digital pulses are input to a digital system which contains the following modules viz. counter and edge detection blocks. The block diagram of the proposed test procedure is depicted in Fig. 3.

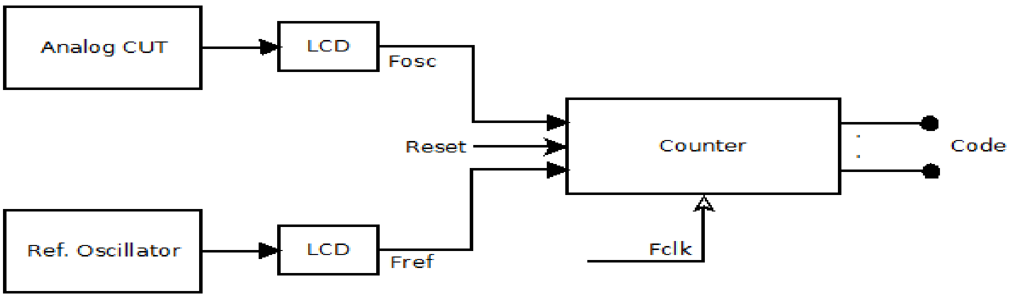

Fig. 3 Test methodology block diagram for frequency to fault code converter

The counter is a simple 16-bit up-counter, it counts until an event from the edge detection circuitry triggers the counter to stop. This happens when the falling edge of the digital pulses from the CUT and reference oscillator coincides, the count on the counter corresponds to the oscillation frequency. The F_{ref} is assumed to be much greater than F_{osc}, this is because the probability of coincidence increases significantly. It is also to be noted that F_{ref} is kept constant for the entirety of the experiment.

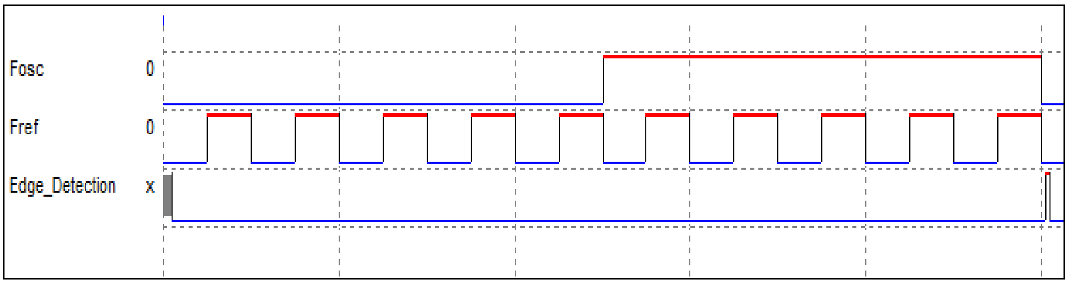

Fig. 4 Waveform depicting Point of Coincidence

The two frequencies, the oscillation frequency (F_{osc}) from the CUT and reference frequency (F_{ref}) from the external circuitry are compared to correspond to a number (N_{POC}). The two frequencies are compared for coinciding falling edge, called the Point of Coincidence, as depicted in Fig. 4. Falling edge is considered, this is because the experiment assumes the input signals to be falling at the start. When the falling edge of F_{osc} coincides with the falling edge of the falling edge of F_{ref}, the event is registered and counter is deactivated and the count corresponds to the fault code for that value of F_{osc}.

In the flowchart, as elucidated in Fig. 5, the module checks the frequencies from the CUT and the reference oscillator for falling edges. Once the falling edge of both the oscillation and the reference frequency is encountered at the same as shown in Fig. 4, the counter is disabled i.e., stops counting.

The clock for the counter (F_{clk}), is independent of the F_{osc}, this is because, if F_{osc} were to be F_{clk}, the sensitivity of the counter would be really low. For this reason, F_{clk} is chosen to higher than F_{ref} and F_{osc}.

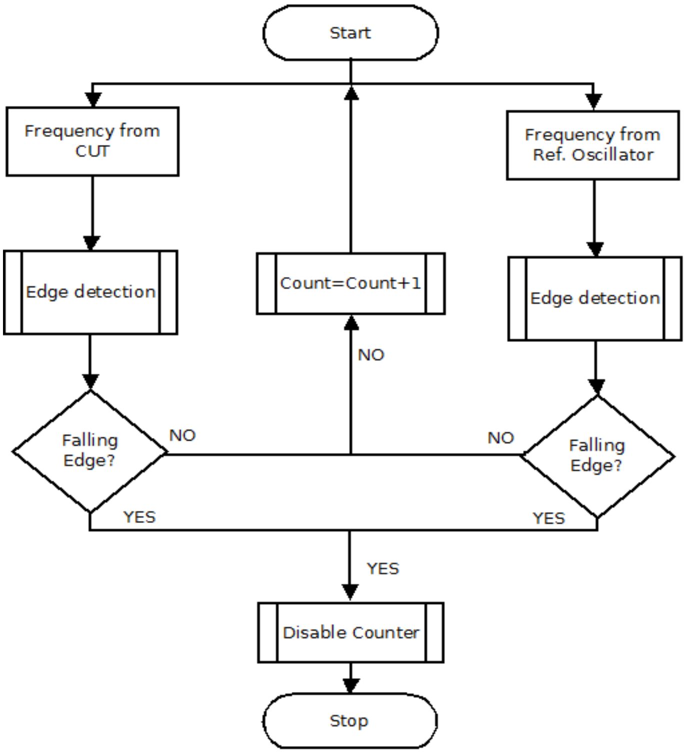

Fig. 5 Flowchart for counter module of the frequency to fault code converter

2.4. Formulation

Let say, F_{osc} = 10MHz and F_{ref} = 100MHz.
This implies, $T_{osc} = 1 / F_{osc}$ = 100ns.
Similarly, $T_{ref} = 1 / F_{ref}$ = 10ns.

T_{POC} i.e., time it takes to get to the point of incidence is estimated by the equation,

$$T_{POC} = LCM\ (\ T_{osc},\ T_{ref}\ ) \qquad \ldots(2)$$

Therefore, using the equation 2, T_{POC} for F_{osc}, when F_{ref} is kept at 100MHz is,

T_{POC} = LCM (100, 10) = 100ns.

Simulation result for the above example is depicted in Fig. 6.

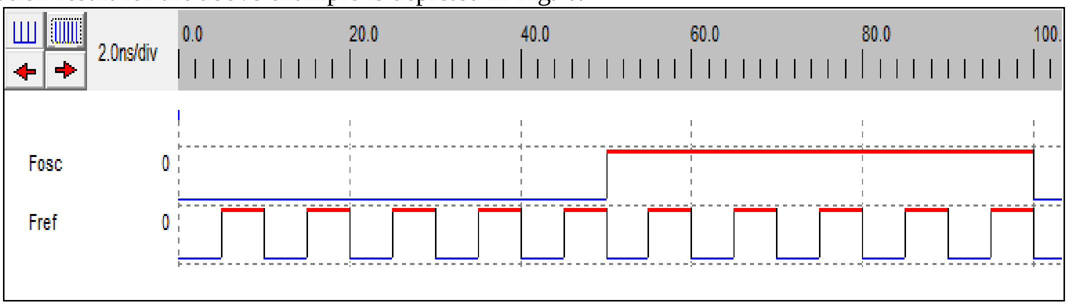

Fig. 6 Waveform depicting the example for estimating T_{POC}

Since, the counter increments at every rising edge of the clock (F_{clk}), therefore it is safe to assume that, the fault code (N_{POC}) is,

$$N_{POC} = T_{POC} / T_{clk} \qquad \ldots(3)$$

Say, for the same example, if T_{POC} = 100ns, and T_{clk} = 5ns.

From equation 3, N_{POC} = 100/5 = 20, the result is depicted in Fig. 7.

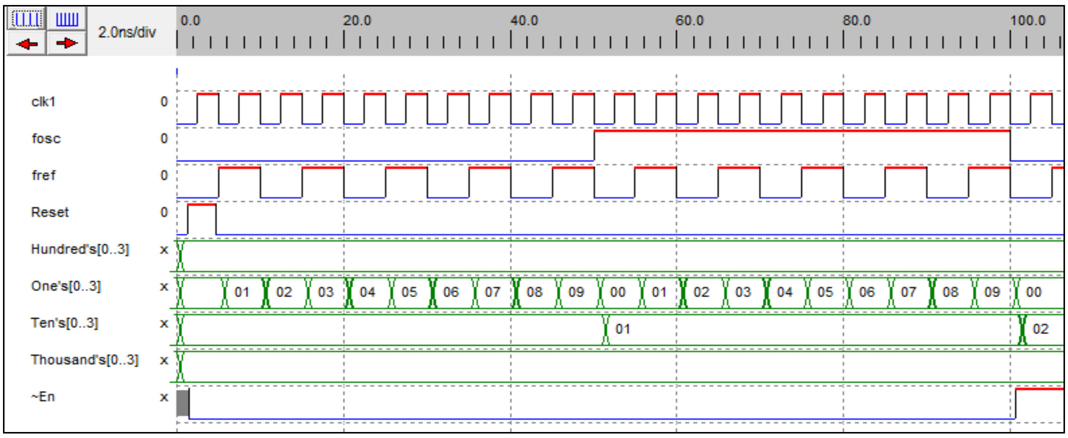

Fig. 7 Waveform depicting the example for estimating N_{POC}

III. RESULTS ACHIEVED AND OBSERVATIONS

This experiment considered RC phase shift oscillator as the CUT. First fault-free oscillation was considered, and the fault code corresponding to it was found out. For fault-detection, faults were injected into the CUT. In this experiment, only catastrophic faults were considered. The component was stuck-short by adding a 10Ω resistor in parallel and stuck-open by adding a 100MΩ resistor in series as shown in Fig. 8. Value of the F_{ref} was kept constant at 20kHz for the entirety of the experiment.

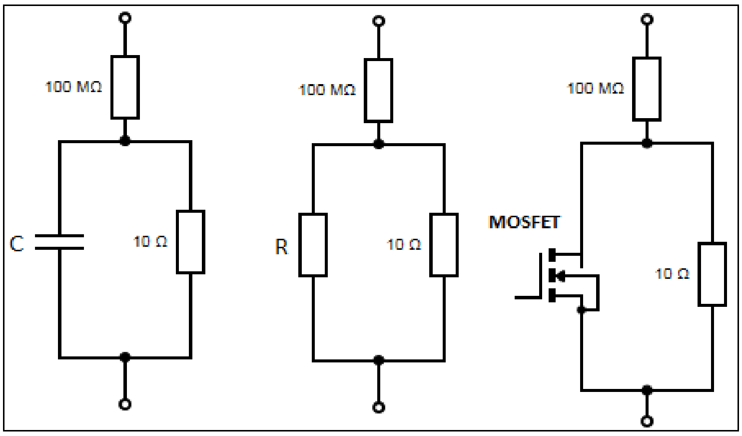

Fig. 8 Stuck-open and stuck-short fault models for capacitor, resistor and MOSFET

Table 1
Simulation results for RC phase-shift oscillator

Faults	Output oscillation freq. of CUT(kHz)	Fault Code (Hex)
Fault free	**5**	**A**
R1 short	4.68	10B
R2 short	7.32	AA
R3 short	8.88	8E
R4 open	1.62	304
C2 open	5.074	F7
C3 open	5.039	E6
Other faults	**No oscillations**	

IV. CONCLUSION

This paper investigates the implementation of Frequency to Fault Code converter using the concept of the point of coincidence, and proposed the integration of Frequency to Fault Code converter and OBIST. The experiment yielded gainful results and can be employed for testing complex analog and mixed-signal integrated circuits.

V. FUTURE SCOPE

This work can be further extended into developing an external testing module, for testing a number of different prototypes. This module can work by reading the values from the Frequency to Fault Code converter viz. the CUT, and look up for that CUTs' derived fault list for result against each code. Each CUT should have the fault list database and must be preloaded into the external testing module.

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