

# Ramp Generator for ADC Built-In-Self Test

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## ABSTRACT

This article aims to explain the development, simulation and layout of a ramp generator, used in a configuration of a ramp BIST. The test objects are the analog-digital converters (ADC). The generator proposed has a ramp with a calibrated slope. This characteristic facilitates some error tests of converters. For this study we used the platform Cadence® associated with the technology XFAB 0.18 microns.

## Keywords

Ramp Generator, Analog-to-Digital Converter, BIST, mixed-signal.

## 1. INTRODUCTION

A good part of the integrated circuits that are manufactured today have analog capabilities in its composition. The integration of highly complex analog circuits is increasingly possible due to improved manufacturing and treatment processes of silicon [1]. Nevertheless, the implementation of a large circuit also promotes greater complexity for testing with the same. The cost of testing an integrated circuit sometimes exceeds the value of the design and manufacture of the circuit itself [2]. The test access for analog front-end and mixed-signal interface (A/D and D/A converters) is limited. Therefore, it is almost impossible to perform the test stimulus and measurements outside the chip [1].

Because of the price growth in the testing of integrated circuits, the use of BIST (built-in-self-test) has increasingly been a great choice for error test. This choice is due to evolution of technology, which promotes circuits increasingly larger and more complex. A good set of BIST methods have been developed to test integrated circuits ADC. Among them we highlight: servo-loop method, histogram method, oscillation BIST (OBIST) method [4] and ramp BIST method [3].

Taking as an object of study the Ramp BIST method, this article aims to explain, develop and test the circuit naming test: Ramp generator. Figure 1 shows the block diagram of the BIST scheme for a generic ADC.

This article proposes to show a ramp generator to be used in ramp BIST for A/D converters. Section 2 presents the types of errors found in ADC. In section 3 it is shown the circuit topology of the ramp generator. In the section 4 is shown the results of simulation, and the structure of the layout. Section 5 is destined to conclusion.

The figure shows and ADC under test which is submitted to test logic. The BIST control promotes the feedback of the circuit.

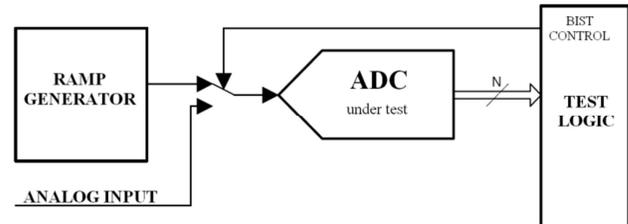


Figure 1: BIST scheme for generic ADC

## 2. BACKGROUND

ADC can have many of types of static errors and faults. Most of them are defined in Figure 2.

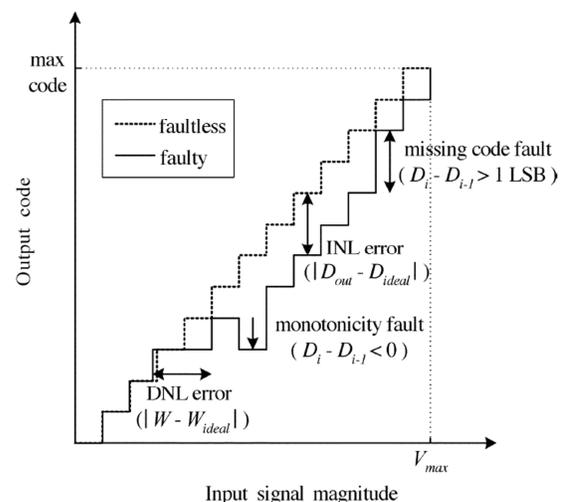


Figure 2: ADC errors and faults

The non-linear errors of a ADC or DAC are calculated in terms of least significant bits (LSB). The LSB is the minimum voltage difference between consecutive codes of an ADC or DAC ideal. A LSB can be defined as:

$$LSB = \frac{V}{2^N} \quad (1)$$

where  $V$  is the full range of the converter with  $N$ -bit resolution.

When the difference current output of the ADC ( $D_i$ ) with a previous output ( $D_{i-1}$ ) exceeds an LSB and the ramp slope is sufficiently low has a *missing code fault*. Ramp to an ever-increasing, has the conversion at some point decreases, the ADC has a *monotonocity fault*. The *INL* (integral nonlinearity) *error* is defined by the difference between the ADC output ( $D_{out}$ ) and the ideal expected output ( $D_{ideal}$ ). The *code width* ( $W$ ) is defined by the width of the analog input that corresponds to 1-LSB digital output. The difference between the measured code width and the ideal code width ( $W_{ideal}$ ) is defined DNL (deferential nonlinearity) error [3].

Applying a ramp to the input of ADC is possible, through a logic test for the same ADC as shown in Figure 1, detecting errors and also to sort them according to the above conditions. For this, however, it is necessary that the ramp is perfectly calibrated and has a known frequency. The proposed circuit achieved satisfactory results for both conditions.

### 3. RAMP GENERATOR TOPOLOGY

To design a ramp generator is necessary to know the frequency to work and have a device that has a linear response to a constant excitation current, which in this case is the capacitor. From equation 1 it is known that the capacitor is an electric-device having at its terminals a voltage given by:

$$v(t) = \int_0^t i(x)dx + v(0) \quad (2)$$

Having a constant current source can produce a linear behavior of the voltage at the capacitor terminals. In other words, to obtain a curve with a slope calibrated to apply a current as constant as possible at the terminals of the capacitor [5]. For the development of this conclusion is necessary to design at the level of transistor, a source of current with little variation of current. To this was used in this article the topology shown in Figure 3. Has a cascode current mirror to increase the loop current that charges the capacitor.

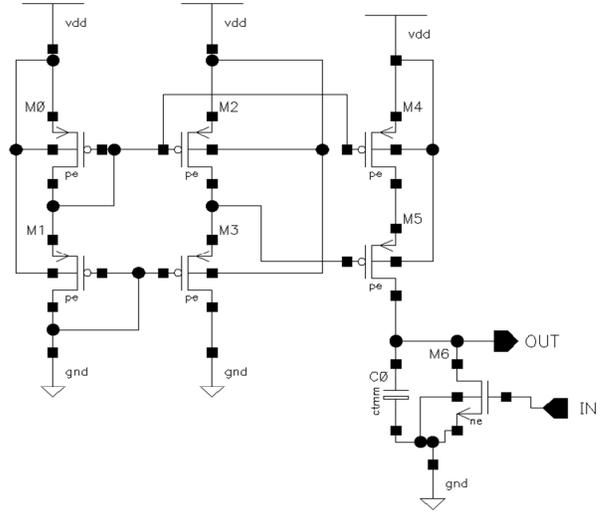


Figure 3: Ramp Generator Circuit

The circuit shown has been made in this manner, although there is a simpler configuration for same. This is due to the need for a ramp calibrated for greater efficiency test DNL and INL. Once the current mirror used should be done so that the current to be as constant as possible.

### 4. RESULTS

Based on the topology of the ramp generator circuit, the same has been assembled and simulated in Cadence® environment. The choice of values of length ( $W$ ) and width ( $L$ ) of transistors was defined by the selection of some fixed parameters of the circuit, such as operating frequency and capacitance of the capacitor. The maximum voltage value is 1.8 volts. It occurs due to technology and fabrication process. Was chosen for this topology capacitance of 5 pF, which in the course of circuit integration represents a considerable size of the capacitor. The frequency was chosen to be 100 KHz. The choice of this specific frequency to ensure sampling from the ADC efficiently.

From the parameters considered, knowing that it must have a constant current, and equation 2 is that:

$$v_c(t) = \frac{1}{C} I \cdot \int_0^t dx + v(0) \quad (3)$$

Considering  $v(0) = 0$ , ie, the capacitor is initially discharged, we have:

$$v_c(t) = \frac{1}{C} \cdot I \cdot t \quad (4)$$

Then for  $C = 5\text{pF}$  and knowing that  $V_C (5 \mu\text{s}) = 1.8 \text{ V}$  (the topology of the ramp 100 KHz is constructed such that

half of the period has the voltage value zero, ie,  $V_{max} = 5\mu s$ ), thus, the current value found is:

$$I = 1.8 \mu A$$

For the current value found, it was found that the values of L and W of the current source and first current mirror stage (M0, M1, M2 and M3) are:

$$W = 12\mu m ; L = 2\mu m$$

This occurs since the technology for these values of transistors produce a current, efficiently and stable, in the current source approximately  $I = 0.45\mu A$ .

By applying the values in the transistors in second stage current mirror, so that the ratio  $W / L$  is four times that of the first stage is that the current passing through the capacitor reaches the desired value approximately:  $I = 1.8 \mu A$ . Thus, the values of W and L obtained experimentally for the second current mirror stage were:

$$W_{4,5} = 48 \mu m ; L_4 = 2.3 \mu m ; L_5 = 2.4 \mu m$$

The values of L and W of the single n-type transistor, whose function is switching from a clock circuit for discharging the capacitor in half the period, were chosen so that the transistors have the smallest value of L as possible in technology and a value of W that is compatible with the necessary connections to the transistor. For the transistor has been established the following values of L and W:

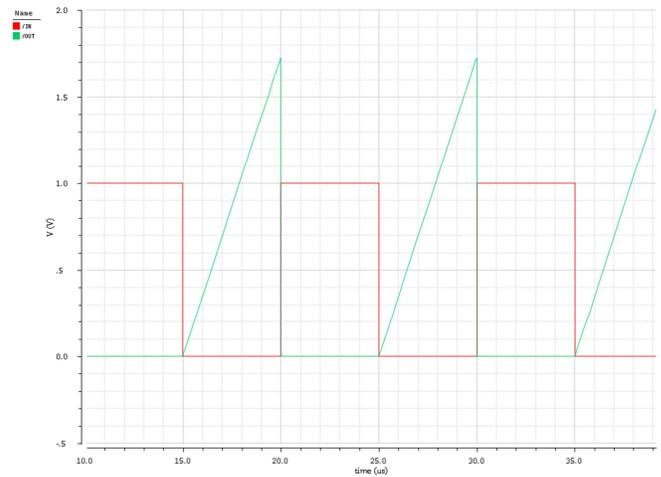
$$W_6 = 10 \mu m ; L_6 = 0.18 \mu m$$

From this information it is possible to mount a table with the values of length and width of the transistors (W and L). *The capacitor has 5 pF of capacitance.*

**Table 1: Width and Length values for Transistors**

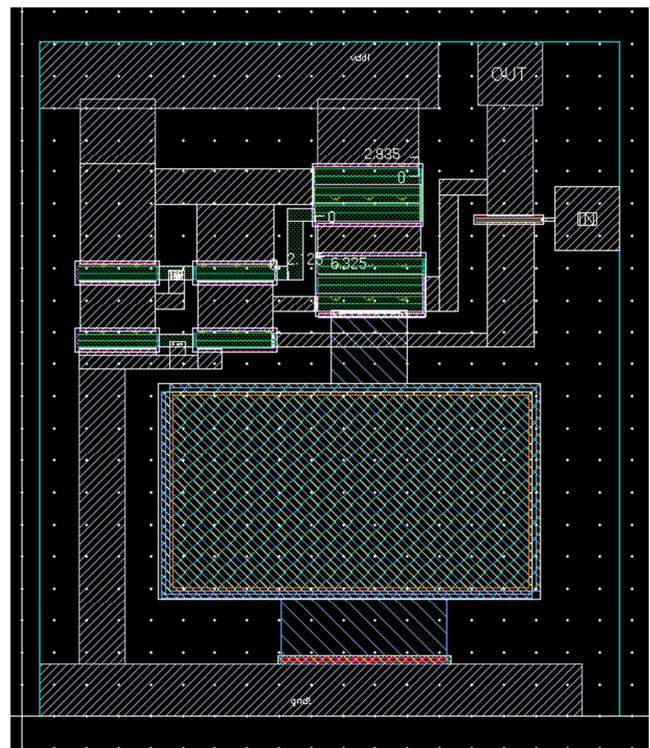
| Transistor | W          | L            |
|------------|------------|--------------|
| M0(p)      | 12 $\mu m$ | 2 $\mu m$    |
| M1(p)      | 12 $\mu m$ | 2 $\mu m$    |
| M2(p)      | 12 $\mu m$ | 2 $\mu m$    |
| M3(p)      | 12 $\mu m$ | 2 $\mu m$    |
| M4(p)      | 48 $\mu m$ | 2.3 $\mu m$  |
| M5(p)      | 48 $\mu m$ | 2.4 $\mu m$  |
| M6(n)      | 10 $\mu m$ | 0.18 $\mu m$ |

With the calculated values, remains to simulation and circuit layout. For the simulation, it applies a square wave of 100 KHz to the gate of the transistor M6 (n-type), and gives the output. For the circuit is obtained as the output shown in Figure 4:



**Figure 4: Ramp generator output**

The layout is done even in the environment Cadence ® is shown below in Figure 5:



**Figure 5: Layout Implementation**

## 5. CONCLUSION

A circuit topology ramp generator with application in Built-In Self-Test for ADC's is proposed in this paper. The need for greater efficiency for the test, through a calibrated ramp was the motivation and provided an expansion of knowledge in the field tests. The results were satisfactory for the job and the circuit has good stability for the proposed conditions.

## 6. ACKNOWLEDGMENTS

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## 7. REFERENCES

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