A Novel Programmable CMOS Based Function Generator Circuit

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Abstract— In this paper, design and analysis of a programmable CMOS-based function generator circuit is presented. The proposed circuit implements trapezoidal and triangular functions with all parameters (slope, position, width and height) independently and continuously adjustable. The proposed circuit achieves higher speed compared to the available previous work by not using winner takes all or looser takes all circuits which are common in design of function generator circuits. The circuit is designed and simulated in 0.13 µm CMOS technology, and is suitable to be used in analog and mixed-mode integrated circuits.

Index Terms— Function generator, Programmable, CMOS, Trapezoidal and triangular functions, Current mode.

1 INTRODUCTION

Function generator circuits are one of the main building blocks of different electronics applications such as analog signal processing, medical devices and communication circuits [1], [2], [3], [4]. In these applications, circuits that perform basic operations like function generators play a great role. Any improvement in their circuit level realization can have significant effect in improving efficiency of the system [5]. Most of the currently available structures for function generators use two operational transconductance amplifiers (OTA) beside a Min or Max circuit. Although many high speed OTAs have been designed and proposed, but the use of the Min or Max circuit [6], [7], [8] limits the speed considerably. This is because the operating speed of the Min or Max becomes dominant and decrease the overall speed of the function generator circuit.

This paper presents a cost effective and simple CMOS function generator circuit which is easy to implement and use. The proposed architecture produces trapezoidal and triangular functions with all parameters (slope, position, width and height) independently and continuously adjustable. The main aim of this work is to realize a linear, low-voltage and high speed CMOS based function generator circuit.

2 PROPOSED FUNCTION GENERATOR CIRCUIT

The voltage to current (V-I) converter circuit shown in Fig. 1 is the main part of the proposed function generator circuit. It can be inferred from this figure that $I_{M1a} = I_b$ (because the gate of $M_{1a}$ does not take any current) and since $I_b$ is constant, $V_{GS1b}$ (and similarly $V_{GS1a}$) has to remain constant (neglecting body effect). Therefore any variations in $V_{in}$ at the gate of $M_{1a}$ or $M_{1b}$ will be reflected to the source terminal level-shifted by the constant gate-source voltage ($V_{GS1a}$ or $V_{GS1b}$). From Fig. 1, we have:

$$I_b = \beta (v_{m2} - v_x - v_{th})^2$$

$$v_x = v_{th2} - v_{th} - \frac{I_b}{\beta}$$

$\beta$, $I_b$ and $V_{th}$ are the parameters of the NMOS transistors.

From (1) and (2) we have:

$$I_{out} = I_{M2a} - I_{M2b}$$

$$I_{out} = 4\beta \frac{I_b}{\beta} (v_{in1} - v_{in2})$$

Fig. 2 shows $I_b$ as a function of $v_{in1}$. The reason for plotting $I_b$ versus $v_{in1}$ instead of $(v_{in1} - v_{in2})$ is that in most of applications one of the inputs is connected to a constant voltage and the other one to the input signal. As it will be discussed, we use this constant voltage to control and adjust different parts of the output current.

The architecture of the proposed function generator circuit is shown in Fig. 3. This circuit is capable of generating trapezoidal and triangular functions. Note that among several classes of parameterized signals, triangles and trapezoids are more commonly used in industrial control applications.

In this structure (Fig. 3) $I_2$ is greater than $I_1$. When the input signal is applied, $I_0$ and therefore $I_{out}$ will begin to increase from zero (part I of Fig. 4). At this state ($I_1 > I_2, I_2$):

$I_{out} = 0$

When $I_1 < I_0 < I_2$ (see Fig. 3), the subtraction of $I_{out}$ from $I_0$ will force $I_{out}$ to remain constant (part II of Fig. 4):

$I_{out} = I_0 - I_1$

When $I_0 > I_1, I_2$, the subtraction of $I_{out}$ from $I_0$ will decrease $I_{out}$ (part III of Fig. 4):

$I_{out} = I_0 - I_1$

$I_{out} = I_0 - I_1 - I_2$

$I_{out} = I_0 - I_1 - I_2 = I_1 + I_2 - I_0$

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4  Speed Consideration

Transient response of the proposed function generator circuit for 50 MHz is shown in Fig. 6(a), where the input is a ramp signal. Fig. 6(b) and (c) compare the high speed characteristics of the proposed circuit with the one presented in [9]. Fig. 6(b) is the response of our proposed circuit for 200 MHz and the response of the circuit proposed in [9] for less than 1 MHz is shown in Fig. 6(c). The major reason for the improvement in the speed of the proposed circuit, compared to the conventional function generator circuits is that the proposed circuit is realized without using Min/Max circuits.

3  Tuning and Programming Function Generator Circuit

The slope of the legs in output current shown in Fig. 4 is dependent on \( I_b \). Fig. 5 shows how this feature can be used to tune the slope of the output current. The slope is also dependent on \( (W/L) \) ratio of transistors, and this feature can also be used to adjust the slope. The LTspice simulation results shown in Fig. 5(a) demonstrates how the slope of the leg can be tuned.

The height of the output wave generated by the proposed function generator circuit can also be programmed. This is achieved by changing or choosing different values for \( I_1 \). Similarly the length of the constant section of the output wave depicted in part II of Fig. 4 can be adjusted by choosing different values for \( I_2 \). The simulation results that demonstrate these features are depicted in Fig. 5(b) and (c).

The start position where the output current starts to increase from zero (part I of fig. 4) can also be adjusted by changing the value of \( V_{in2} \). The simulation results that demonstrates the function of this feature is depicted in Fig. 5 (d).

Fig. 1. (a) V-I converter, (b) current subtractor.

Fig. 2. Simulation result of V-I converter.

Fig. 3. Proposed function generator circuit.

Fig. 4. Function generator output.
5 CONCLUSION
In this paper a CMOS-based function generator circuit has been designed and analyzed. Our proposed circuit can implement trapezoidal and triangular functions with all parameters (slope, position, width and height) continuously tunable. The proposed circuit achieves higher speed compared to the available works by not using winner takes all or looser takes all circuits which are common in design of function generator circuits.

Fig. 5. Illustration of how the output current generated by the proposed function generator can be tuned.

Fig. 6. (a) Response of the proposed function generator circuit to 50 MHz. (b) Response of the proposed function generator circuit to 200 MHz. (c) Response of the function generator circuit presented in [9] to less than 1 MHz.
REFERENCES


