Designing of a Digital to Analog Convertor Fully in CMOS, 0.18µm, 1.8V Technology with SFDR more than 70dB

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Abstract

Background/Objectives: Nowadays in new system of communication, analog to digital and digital to analog converters are used plenteously. Digital to analog converters are converters that receive digital data and convert it to an analog signal. Methods/Statistical Analysis: In this study a digital to analog converter has been fully designed in CMOS, 0.18µm, 1.8V technology. Findings: Designed converter receive 6 low-worth first bits in the form of binary and 4 worthy last bits in the form of unary thermometer codes. Output of this converter is in the form of sinusoidal signal. This converter has high amounts of SNR and SFDR. Application: In conclusion, this study illustrated that different methods of designing can be compounded to achieve to complex designing with better performance.

Keywords: Analog, Converter, Digital, Unary Thermometer Code

1. Introduction

This article deal with say acquired result of a research about design, simulation and survey performance of a digital to analog convertor that is designed in the complex form. Nowadays in New system of communication, analog to digital and digital to analog converters are used plenteously. Analog to digital converters are converters that receive analog data and convert it to digital signal and Digital to analog converters are converters that receive digital data and convert it to analog signal. There are different methods to design digital to analog converters and each method has its benefits and sins. We can compound different methods of designing different parts of digital to analog converters to achieve to complex designing. Complex designs are very common methods in converters designing because compound different methods points1,6 frequency mutation decreased much with unary thermometer code method for MSBs (worth bits) and with binary size method for LSBs and accuracy is obtained for worthy bits that are most in need. However in part of low, worthy bits the matter of mutation and accuracy is included less but worthy frugality in the level of binary method is done. In continuation we deal with expression of demands and design of converter [1]1,2,5.

2. Design

2.1 Expression of Design Demands

Purpose is designing of a digital to analog convertor fully in CMOS, 0.18µm, 1.8V technology with following specifications:

- Resolution: 10-bit
- SFDR > 70dB ( f_{clk} = 150MSPS, f_{out-max} = (k/M)f_{clk}, k = 256, M = 4096 )
- The digital sinusoidal input should scan all possible codes

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In design the DAC according to Figure 1 should be performed 6 low-worth first bits in the form of binary and 4 worthy last bit in the form of unary thermometer code. We must select current source from cascade type as Figure 2.

![Figure 1](image1.png)

**Figure 1.** Scheme of the digital to analog converter that is wanted to design.

![Figure 2](image2.png)

**Figure 2.** Scheme of the cascade current source that is used in to digital to analog converter of Figure 1.

### 2.2 Current Source Design

At first we should design current source to start. In the first place we determine amount of W and L according to transistors performance in accordance with Figure 2.

For this according to said technology we have:

- \( L = 0.18\mu m \)
- \( W_1 = 1.8 \mu m \)
- \( W_2 = 1.8 \mu m \)
- \( W_3 = 0.36\mu m \)
- \( W_4 = 0.36\mu m \)

Now with knowing these amounts and supposing M3 and M4 transistors do at saturation area, we calculate \( V_{bn1} \) and \( V_{bn2} \) voltages manually to have intended \( I_u \) current. Then we write a net list file with manual calculations results and design \( V_{bn1} \) and \( V_{bn2} \) with computer and Hspice software and with intended technology, result will be as:

- \( V_{bn1} = 520mV \)
- \( V_{bn2} = 580mV \)

### 2.3 Filter

In use filter in this project is a 3 stage Butter worth filter with Sallen Key format. If we design filter to have 10MHz cut-off frequency, filter specifications are such as Table 1 and its scheme is such as Figure 3.

![Figure 3](image3.png)

**Figure 3.** Scheme of the 3 stage Butter worth filter with Sallen Key format.

| element | amount  | element | amount |
|---------|---------|---------|--------|
| R1      | 11kΩ    | C1      | 1.5PF  |
| R2      | 110kΩ   | C2      | 0.68PF |
| R3      | 33kΩ    | C3      | 0.1PF  |

The Bode diagram, Nyquist diagram and step response of the Fillter of Figure 3 are such as Figure 4.

![Bode Diagram](image4.png)

a) Bode diagram.
2.5 Design of Digital to Analog Converter

In previous part we introduced and design different parts of digital to analog converter of Figure 1. Here we want to design and simulate circuit of Figure 1 with designed parts in previous parts. For this we use Hspice 2008 software. For design and simulation we should notice that in each part of circuit regarding index of $I_u$ must have as number of current sources. For example in unary segmentation part from $d_1$ to $d_{15}$, current source is used 15 times that each time regarding index of $I_u$ is equal with 64, so we should use current source 64 times.

For generation of entrance signal, we consider two DC voltage source that connect in one way to current source entrances and in other way to the ground and describe them for $d_1$ to $d_{15}$ and $b_5$ to $b_{10}$. Amount of these DC sources in each time is very our digital codes. We describe these sources with a digital sinusoidal function that can cover all of the possible codes. For example Figure 6 and Figure 7 respectively are related to $d_1$, $d_1b$ and $b_5$, $b_5b$ entrances.

The gain of used buffer in circuit equal 1, then we select transient analysis type and use .PRINT and .PROB orders to print and draw output voltage. Wave forms of output voltage before filter ($V_{o2}$) and after the filter ($V_o$) will be as Figures 8 and 9.

Notice that incoming digital signal has converted to a sinusoidal signal.
2.6 Calculation of SNR and SFDR

We take related data of voltage of output node \( (V_o) \) and then calculate related amount of SNR\(^1\) and SFDR\(^2\) with Matlab software. Figure 10 is related to calculation of SFDR that has got with Matlab software. Amount of SNR and SFDR are equal with:

\[
\text{SNR} = 61.7590\text{dB} \\
\text{SFDR} = 73.3218\text{dB}
\]

Figure 10. Wave forms for calculation of SFDR.

We notice that amounts of SNR and SFDR of the digital to analog converter of Figure 1 are respectively 61.75dB and 73.32dB that both of them are considerable and even are more than wanted amount in design conditions.

Its output is in the form of sinusoidal without distortion too. The reason of this matter is using filter in output of circuit.

Totally as we had also said, mixed designs are very common methods in design of converters, because they compound different methods points.\(^1,2\).

3. Conclusion

In past, different digital to analog converters has designed with different characteristics\(^7\). But designed converter of this paper is in kind of complex digital to analog converters.

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