Down-converter solutions for 77-GHz automotive radar sensors in 28-nm FD-SOI CMOS technology

Radio Frequency Advanced Design Center

Ph.D. Student: Claudio Nocera

Tutor: Prof. Giuseppe Palmisano

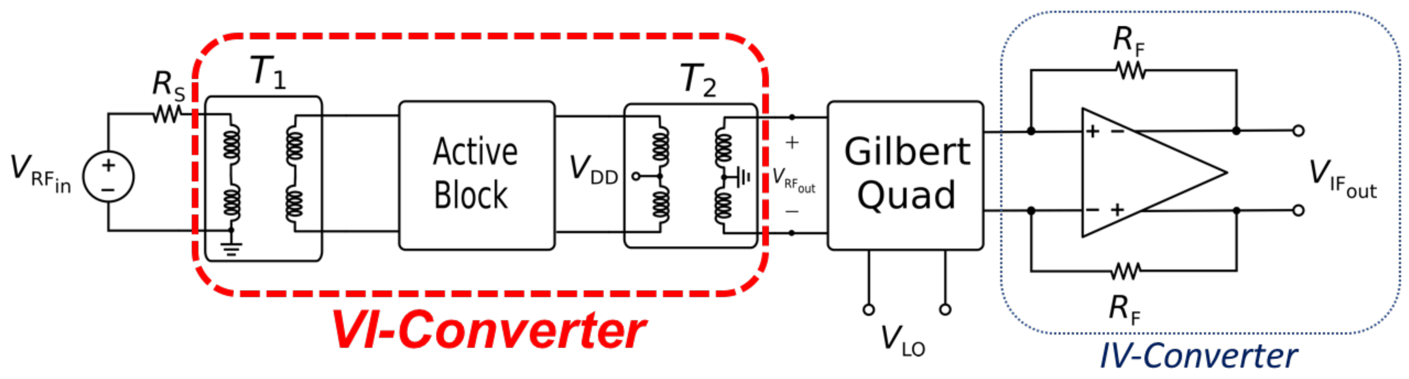
Ph.D. Brainstorming Day - Oct. 9th 2018

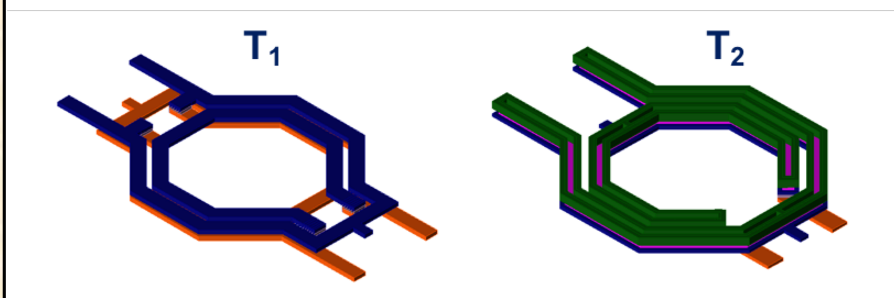
I.Introduction

In recent years, 77-GHz radar sensors have gained high interest due to their application in Advanced Driver Assistance Systems. Highly scaled CMOS technologies are very promising to implement low-cost mm-wave automotive radar systems since they enable System-on-Chip (*SoC*) implementation including the mm-wave front-end, the analog base-band, and the digital processing circuitry. One of the most critical building block is the down-converter, which has stringent requirements in terms of noise figure, linearity, and power consumption. Although different solutions have been proposed, the best trade-off between linearity and noise performance is provided by mixer-first architectures. In this work, a comparison of two 77-GHz down-converter solutions in 28-nm FD-SOI CMOS technology based on common-source (*CS*) and common-gate stages (*CG*) is reported.

II. System Description

A simplified schematic of the proposed architecture is shown below. The two down-converters share almost all the components with the exception of the voltage-to-current (*VI*) converter that is based on the *CS* or the *CG* stage.





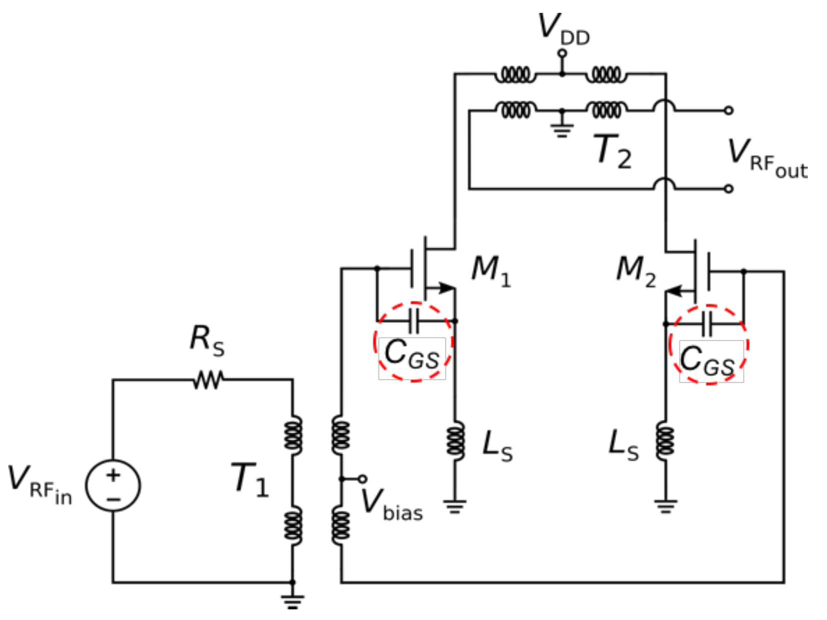
Interstacked transformer   Interleaved transformer

Parameters	Interstacked	Interleaved	Units
L_P @77 GHz	72	103	[pH]
L_S @77 GHz	72	82.3	[pH]
Q_P @77 GHz	18	23	-
Q_S @77 GHz	18	24.5	-
f_{SR}	174	220	[GHz]
k @77 GHz	0.68	0.5	-
IL @77 GHz	5	6.5	[dB]

Frequency response and losses are highly dependent from the integrated transformers, T_1 and T_2. The most critical component is T_1, since its insertion loss (*IL*) directly contributes to the overall receiver noise figure (*NF*). An advanced transformer structure, namely *interstacked*, was evaluated and adopted for the input of the *VI* converter. Each transformer coil is built by shunting two spirals of top metal layers, using complementary structures for primary and secondary windings. Indeed, it takes advantage of both interleaved and stacked trasformers. T_2 was implemented by means of a traditional interleaved structure to maximize quality factors (*Q*), while allowing down-converter gain to be increased.

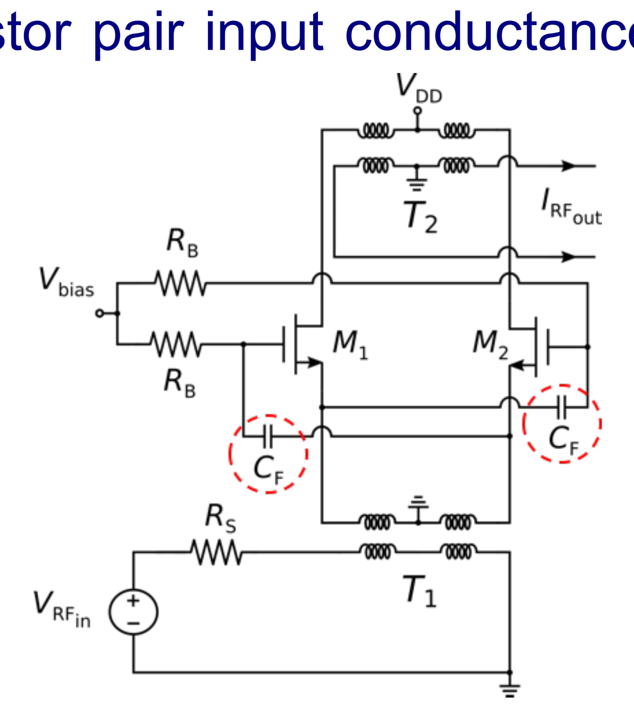
III. Common Source VI-Converter

The real-part input matching is achieved with the degeneration inductances, L_S, whereas the secondary coil inductance of the input transformer is used for the imaginary-part input matching. Minimum *NF* requires optimum gate-source voltage, which is achieved with the optimum current density. The gate area is instead set to make the optimum source resistance for the noise factor equal to the resistance at the secondary coil of T_1. A gate source capacitance, C_{GS}, is included, which avoids that the optimum source resistance leads to a very high aspect ratio and hence to high current consumption.



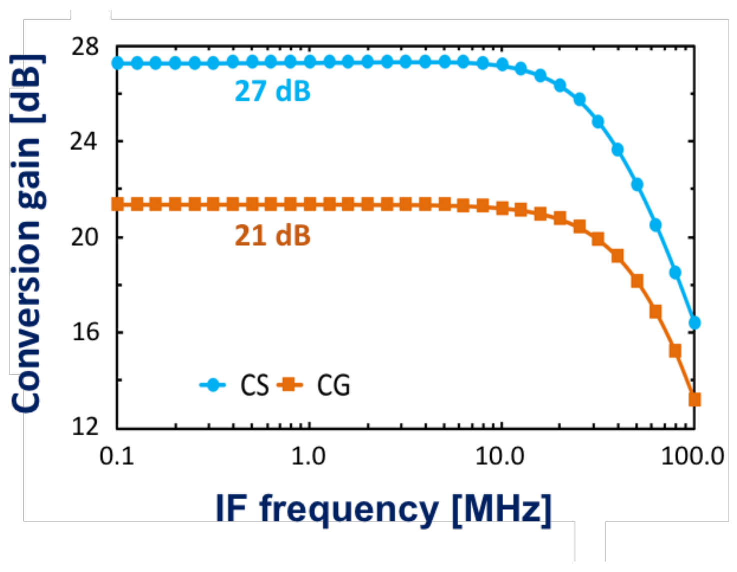
IV. Common Gate VI-Converter

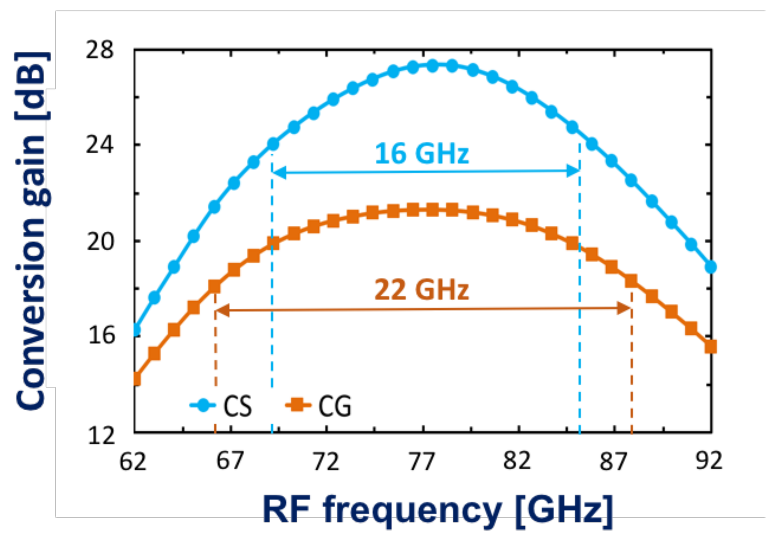
The real-part input matching is achieved by setting the trans-conductance of transistors M_1 and M_2. This usually leads to high bias current for the input pair, so excessive power consumption. To overcome this drawback, feedback capacitors, C_F, are included, which determine an increase in the transistor pair input conductance by a factor 2. This means that the value of $gm_{1,2}$ useful for the input matching is reduced by a factor 2, thus saving power consumption. They also allow a reduction of the input pair noise. This means that a common-mode noise component of 1/4 arises thanks to C_F, giving a noise reduction by a factor 3/4.

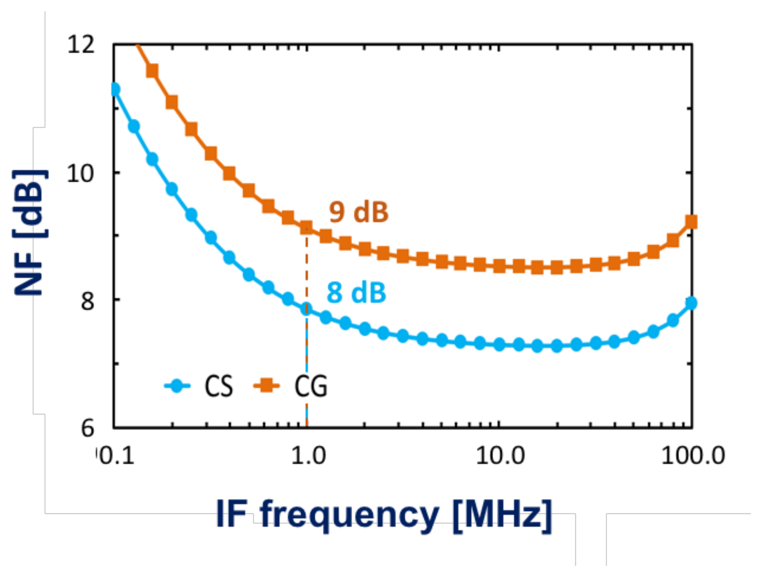


V. Simulation Results

The comparison between *CG* and *CS* down-converters is carried out by using the same power supply (1 V) and current supply (15 mA). The *CS* down-converter achieves better performance in terms of noise figure and conversion gain with values of 7.8 dB and 27.5 dB, respectively, while the *CG* down-converter exhibits a −3-dB bandwidth of 22-GHz, which is 6-GHz wider than that one of the *CS* solution. The *CS*-based down-converter is the best solution for low-noise and high-gain applications, whereas the *CG*-based down-converter is more suitable for wide-band applications.







PERFORMANCE	CS	CG
Noise figure	☺	☹
Gain	☺	☹
Input matching	☹	☺

C. Nocera, A. Cavarra, G. Papotto, E. Ragonese and G. Palmisano, "Down-converter solutions for 77-GHz automotive radar sensors in 28-nm FD-SOI CMOS technology", *in 14th Conf. on Ph.D. Research in Microelectronics & Electronics (PRIME 2018)*, Prague, Czech Republic, 2018, pp.153-156.