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A NOVEL APPROACH FOR DESIGN OF GILBERT CELL USING 90nm TECHNOLOGY

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ABSTRACT:

In this paper we have analyzed various design constraints and considerations while implementing Gilbert Cell in Cadence Virtuoso. Leveraging on the CMOS 90nm technology, which is more suitable for RF and mixed signal designs where Gilbert Cells find extensive applications, our paper aims at improving the performance of Gilbert Cells for various communication systems by investigating on its performance as phase detector and RF mixer. Potential future directions for improving Gilbert Cells for high precision signal processing application have also been explored.

KEYWORDS:

CMOS TECHNOLOGY, GILBERT CELLS, CMOS TECHNOLOGY, PHASE DETECTOR, RF MIXER.

INTRODUCTION

The Gilbert cell is a fundamental building block in RF (Radio Frequency) circuit design, owing to its wide range of applications frequency translation, modulation, demodulation, integrated design and gain control. The Gilbert cell exhibits excellent linearity characteristics, making it suitable for maintaining signal fidelity and minimizing distortions in RF circuits. Gilbert cells often demonstrate low noise figures, making them suitable for sensitive RF applications that require high signal-to-noise ratios. They also provide high isolation between the input and output ports, which helps prevent unwanted signal leakage and interference.

Additionally, Gilbert cells can handle both single-ended and differential signals, allowing flexibility in circuit design. They are often used in combination with other circuit elements, such as mixers, oscillators, and filters, to build complex RF and microwave systems. The Gilbert CMOS as RF mixer is explored for communication applications [1-2]

Gilbert cells are integral to the operation of PLLs, which are widely used in communication systems for frequency synthesis, clock generation, and synchronization. Many literatures are available on Gilbert Cell for various applications like PLL, etc. [3-5]

THE GILBERT CELL ARCHITECTURE OFFERS SEVERAL ADVANTAGES:

1. HIGH LINEARITY: The balanced differential amplification reduces distortion and improves linearity, making it suitable for demanding RF applications.

2. GOOD ISOLATION: The architecture provides inherent isolation between the input and output ports, minimizing interference between signals.

3. WIDE BANDWIDTH: The Gilbert cell's balanced design allows for operation over a broad frequency range, making it suitable for various RF applications.

4. LOW POWER CONSUMPTION: Compared to other mixing architectures, the Gilbert cell can achieve good performance with relatively low power consumption.

This paper is organized into four sections. Section I gives the introduction related to Gilbert Cells and its application as phase detector and RF mixer. Section II describes the design of Gilbert Cell. Section III elaborates on the results and discussions. Section IV presents conclusion.

GILBERT CELL DESIGN

A. CIRCUIT DESIGN:

Gilbert cell is realized in cadence using gpd90 library. The inputs to the Gilbert cell are typically an RF signal and a Local Oscillator (LO) signal. The LO signal is applied to the switching stage, which alternately enables or disables the amplification of the input signal. This action effectively mixes the RF and LO signals and produces an output signal containing the sum and difference frequencies of the two inputs. Gilbert cell, from design perspective, is composed of three stages namely the load stage, switching stage and the transconductance stage. Initially a differential amplifier was designed to obtain maximum differential output gain for 90nm technology. A constant current source as is conventional in the gilbert. Then two such differential pairs having opposite gains $\frac{\text{Vout1}}{\text{Vin}} = -g_m r_d$

this text box.

and $\frac{\text{Vout2}}{\text{Vin}} = +g_m r_d$ respectively. The two outputs $Vout1$ and $Vout2$ are added following the equation,

$$Vout = Vout_1 + Vout_2$$

and the differential output is obtained.[6] In an effort to improve the output gain, initially we worked on the current source value. Further on, we have tried replacing the resistor loads with diode connected loads, since equivalent resistance essentially becomes

$$Req = \frac{1}{g_m}$$

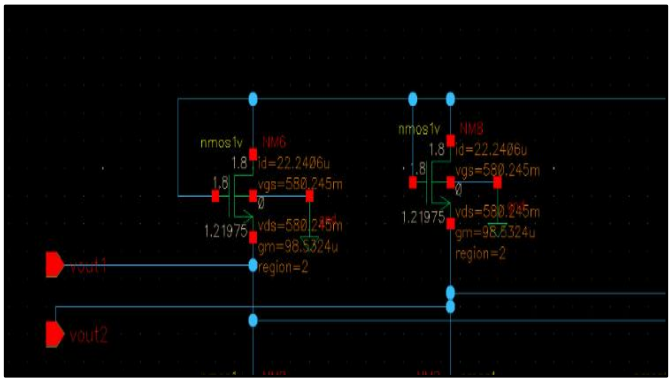

FIG. 1 DIODE CONNECTED LOAD

The Fig.2 shows the design of Gilbert cell in cadence tool. From a design perspective, it is imperative that Gilbert cell consumes larger voltage headroom than simple differential pairs, as it essentially is a cascaded structure.The specification Gilbert cell design using 90nm technology in cadence is given in Table 1

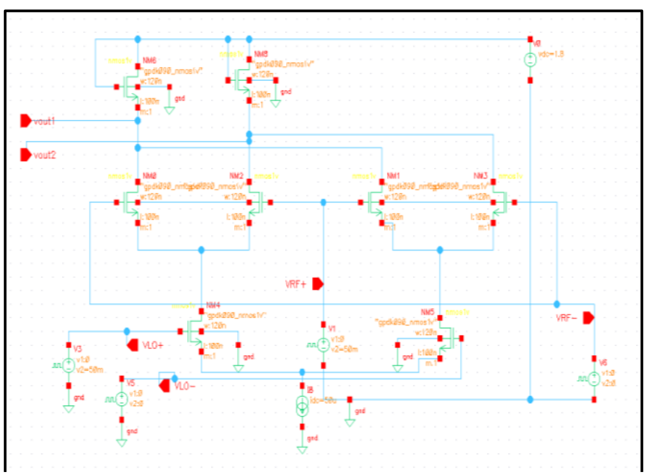

FIG. 2 CADENCE SCHEMATIC OF GILBERT CELL

TABLE 1 SPECIFICATIONS OF GILBERT CELL DESIGN IN CADENCE

Cadence specifications (gpdk90 lib):	
VDD	1.8V
Aspect ratio $(\frac{W}{L})$	$(\frac{120\mu}{100\mu})$
Current source(idc)	50μA

B. RF MIXER

The primary application of the Gilbert cell is in RF mixers as it is a type of double balanced mixer multiplying RF signal with LO signal to produce IF (intermediate frequency) signal.

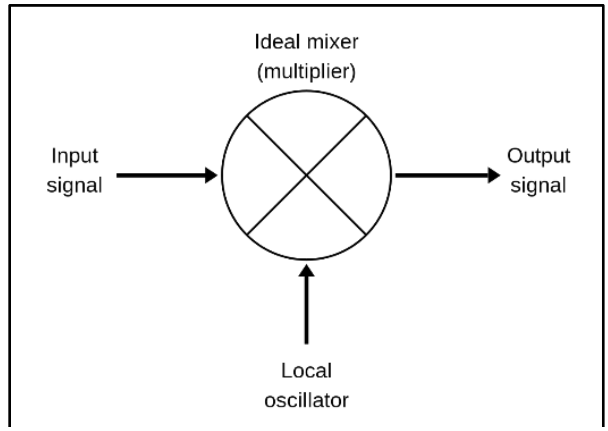

FIG. 3 RF MIXER

Input signal specifications of RF mixer is tabulated in Table 2

TABLE 2 INPUT SPECIFICATIONS OF RF MIXER

Input Specification:		
Input signal 1 (VLO+)	Voltage Frequency	+50mV 100 MHz
Input signal 1 (VLO-)	Voltage Frequency	-50mV 100 MHz
Input signal 2 (VRF+)	Voltage Frequency	+50mV 70 MHz
Input signal 2 (VRF-)	Voltage Frequency	-50mV 70 MHz

C. PHASE DETECTOR

We have tried to analyse the designed Gilbert's cells performance as a phase detector by applying two identical signals with different phase. The phase difference between the two inputs is reflected proportionally in the DC component of Gilbert Cell's output. The Gilbert Cell thus takes advantage of its XOR gate like behavior[7]. The block diagram of phase detector is given in Fig.4. Input signal specifications of phase detector is shown in Table 3.

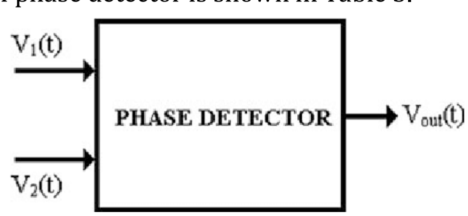

FIG. 4 PHASE DETECTOR

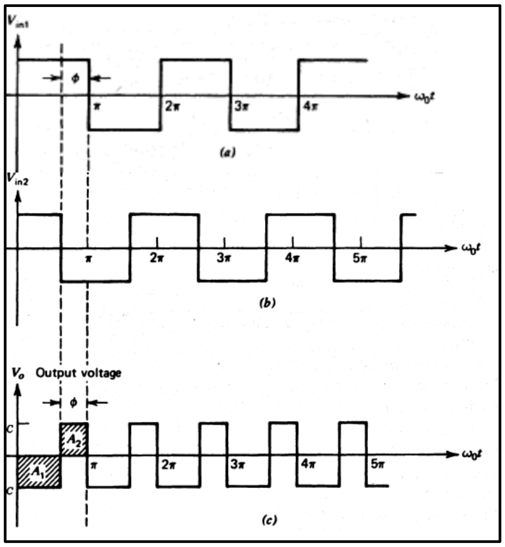

FIG. 5 PHASE DIFFERENCE OF TWO SIGNALS

TABLE 3 INPUT SIGNAL SPECIFICATIONS FOR PHASE DETECTOR

Input Specification:		
Local Oscillator (LO)	Frequency	1KHz
Radio Frequency (RF)	Frequency	1KHz

RESULTS AND DISCUSSION:

The following is the DC and AC analysis of Gilbert cell simulated using Cadence Virtuoso tool. Various parameters like the gate-source voltage, drain current, gm were found using the DC analysis.

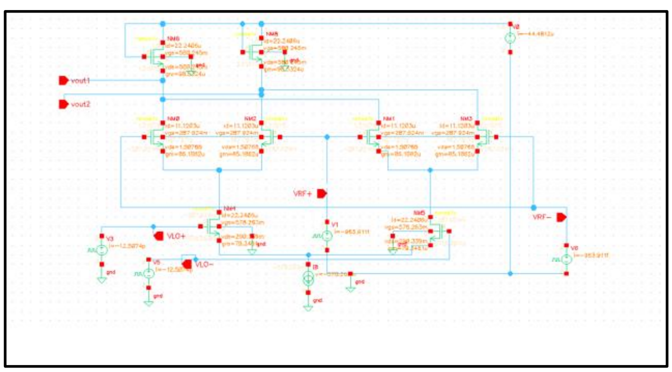

FIG. 6 RESULT OF DC ANALYSIS

The gm value of the diode loads is reduced to increase the voltage gain. The AC analysis gives further insight into the gain against frequency plot of the Gilbert cell. It is shown in Fig.7.

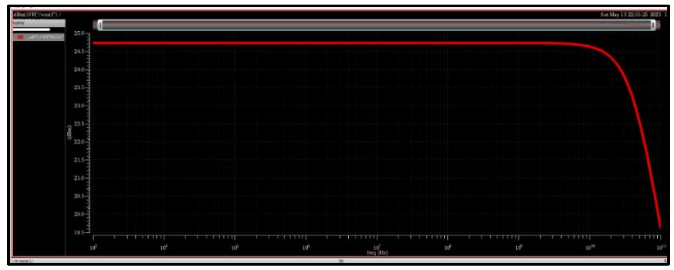

FIG. 7 RESULT OF AC ANALYSIS

The transient analysis with identical pulse inputs allows the analysis of Gilbert cell for phase detector applications. The output of phase detector is shown in Fig.8. The output signal clearly shows the phase difference between the two input signal.

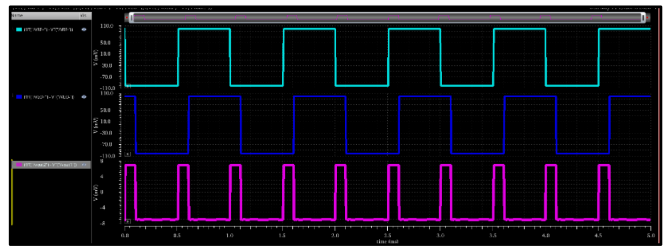

FIG. 8 GILBERT CELL AS PHASE DETECTOR

Again, a transient analysis with two sinusoidal inputs each of different frequency to the Gilbert Cell produces the output which is the product of the two input signals and thus highlights application of Gilbert cell in RF mixers. The output of RF mixer is shown in Fig.9.

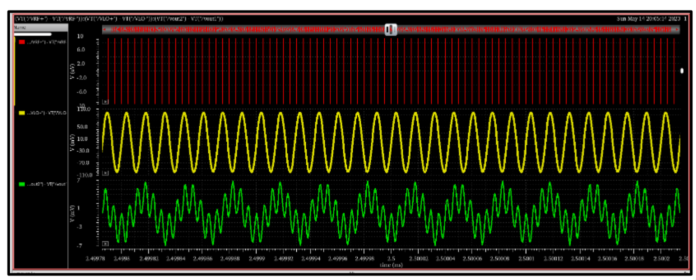

FIG. 9 GILBERT CELL AS RF MIXER

CONCLUSION

In this paper, we have implemented a Gilbert cell with diode connected load in Cadence virtuoso tool using 90nm Technology. The Gilbert cell successfully operates as a mixer at a frequency of 100 MHz It was also successful in detecting the phase difference of signals which is confirmed by performing XOR operation on input signal.

Further DC and AC analysis was performed to study the voltage levels, region of operation and bandwidth. From the results, the performance was found to be satisfactory.

Though the current design of the Gilbert cell works well from the frequency perspective, the gain of the output signal produced is low. There is a lot of scope for improving the gain of the Gilbert cell which can be exploited in the future. Furthermore, layout of Gilbert cell can also be designed.

REFERENCES

1. Pandram, M. K., &Gurjar, R. C. (2014). A low power down conversion CMOS Gilbert mixer for wireless communications. *International Journal of engineering Research and Applications*, *1*, 186-190.

2. Katarmal, A., Mecwan, A., & Patel, M. (2021). *RF CMOS Double Balanced Gilbert Cell Mixer for 5G Application. 2021 3rd International Conference on Signal Processing and Communication (ICPSC).*

3. S. Hokrani, T. C. Thanuja and K. V. Kumaraswamy, "Design and implementation of Phase Locked Loop on 180nm Technology node," *2018 4th International Conference for Convergence in Technology (I2CT)*, Mangalore, India, 2018, pp. 1-6, doi: 10.1109/I2CT42659.2018.9057996.

4. Tsai, J. H., Wu, P. S., Lin, C. S., Huang, T. W., Chern, J. G., & Huang, W. C. (2007). A 25–75 GHz broadband Gilbert-cell mixer using 90-nm CMOS technology. *IEEE Microwave and wireless components letters*, *17*(4), 247-249.

5. S. S. Rout and K. Sethi, "Design of High Gain and Low Noise CMOS Gilbert Cell Mixer for Receiver Front End Design," *2016 International Conference on Information Technology (ICIT)*, Bhubaneswar, India, 2016, pp. 1-5, doi: 10.1109/ICIT.2016.014.

6. Design of Analog CMOS integrated circuits, by BehzadRazavi, Professor of Electrical Engineering, University of California, Los Angeles.

7. B. Razavi, "RF Microelectronics", Pearson Education, 2nd Edition, 2012