Comparative Analysis of Class-A & Class-E CMOS Power Amplifier in 45nm Technology

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Abstract- *Two classes of power amplifier that is class-A and class-E are fabricated at 76GHz frequency and in 45nm CMOS technology. Comparative analysis of two classes has been presented in this paper. Class-A power amplifier provides 46.74mW output power, 17.37dB power Gain, 10.21mW output power dissipation, 135.6fs delay and Kf which is Rowlett stability factor has value 34.847. While Class-E power amplifier provides 128.96mW output power, 21.1dB power gain, 164.1uW output power dissipation, 1.106ps delay and 7.43 is the Rowlett stability factor.*

Keywords- Power Amplifier, Power-added Efficiency, Complementary Metal-oxide semiconductor, Radio frequency.

I. INTRODUCTION

In advanced wireless communication industry, fully integration of analog, digital & even RF function is required in order to reduce manufacturing cost, size & to make power efficient. CMOS allow full integration of a complete radio system on a single chip, which would result in a considerable size and cost reduction. Power amplifier is one of the most important parts of every RF transmitter. Power Amplifier is the main energy consuming part in the RF transceivers. The design of a fully integrated power amplifier with a reasonable output power, power dissipation & gain remains one of the major challenges in today's pursuit of a single chip integrated transceivers. High frequency power amplifiers have received little attention and still remain as a challenging RF block. In this paper, we have presented class-A and class-E design circuits as well as its simulation analysis of various performance parameters at high frequency of 76GHz and in 45nm technology. The comparative analysis of class-A and class-E power amplifier performance parameters has been analyzed in this paper [6] [7][8].

A. Class-A power Amplifier

The Class-A PA, Figure 1, is the most linear PA with a transistor biased such that it never turns off. The conduction angle is defined as the portion of the input signal for which the transistor conducts, meaning that a Class-A PA has a conduction angle of 360 degrees. Because of the non-abrupt drain current, the linearity of this amplifier is certainly high, but it suffers from low efficiency for the same reason. In actual, the relationship is not that perfectly linear, but the ideal model is used since it is very good from an analytical perspective. The output voltage is the signal current multiplied with the load resistance. Due to the large supply inductor, only DC current flows through the inductor, and as a result, the signal current is just the signal component of the drain current. The drain voltage is the sum of the signal voltage and DC voltage and as the inductor is short-circuited for DC frequencies, the DC drain voltage is the supply voltage. In this configuration, common source stage with output matching circuit has been used. In this circuit, the drain inductor (L_d) and its parasitic resistor (R_d), the output parasitic capacitor (C_o) which includes parasitic of the transistor or the drain inductor, and the output matching network includes a series capacitor (C_s) and an inductor (L_p) with its parasitic resistor (R_p). RF inductor at the drain is used for biasing [6][8].

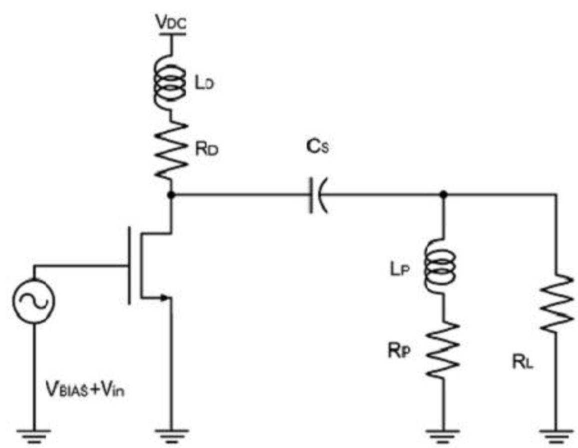

Figure 1:Class-A power amplifier circuit [6]

B. Class-E power amplifier

Class E power amplifier is a highly efficient amplifier used for RF applications. The basic circuit of a Class E amplifier is shown in Fig. 2. The main reason for using the Class E RF power amplifier is that the transistor turns on as a switch at zero voltage, resulting in zero switching loss and higher efficiency. In fact, the parasitic capacitance of the switch can become part of *C*1. In other words, the parasitic drain-source capacitance can become part of the amplifier circuit, which is a big advantage, in CMOS. The combination of the L-C-R series-resonant circuit and the dc feed inductor acts as a current source whose current is IL − IR. When the switch is closed, the current IL − IR flows through the switch. When the switch is opened, the current IL − IR flows through capacitor C_1, produces the voltage across the shunt capacitor C_1 and the switch. Therefore, the shunt capacitor C_1 shapes the voltage across the switch. For the most favorable operation, the zero voltage switching and zero slope switching conditions must be satisfied simultaneously:

$V_{ds}(T) = 0$

$dV_{ds}(t)/\mathrm{d}t = 0$

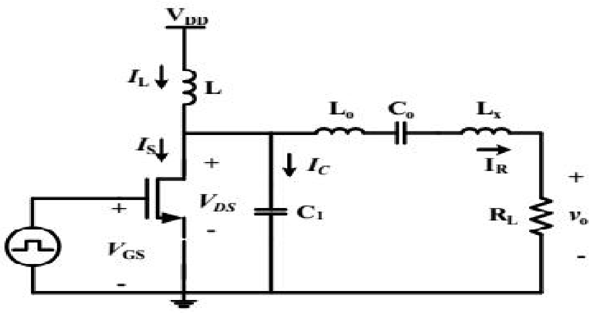

Figure 2: Class-E power amplifier circuit [7]

Class-E power amplifier has two main advantages: a) soft switching that reduces the losses, and b) simple circuit topology compared to other switch-mode PA classes. However, Class-E power amplifier also has some disadvantages: the drain voltage has a high peak value due to charging the large output capacitance. But the sub-optimum mode can be applied to lessen the peak drain voltage at the cost of drop in efficiency. To sustain high efficiency, using a high voltage breakdown device is a good option to design the Class-E power amplifier [1] [2] [3] [4] [5].

II. RESULTS FROM SCHEMATIC

A. Schematic of Class-A PA

The schematic of class-A power amplifier is successfully designed in the cadence tool in 45nm technology.

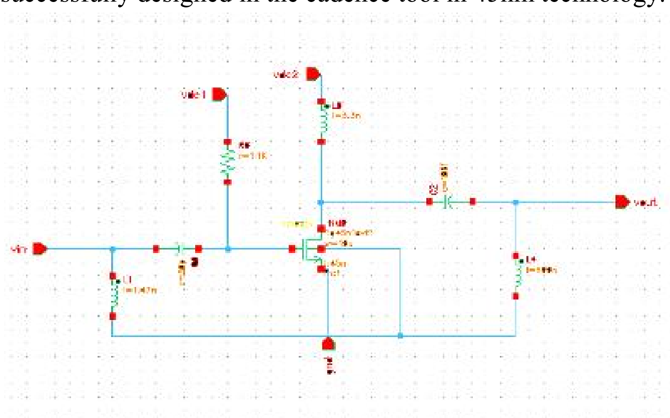

Figure 3:Schematic of class-A power amplifier

B. Transient Response of class-A power amplifier

a) Voltage Waveform

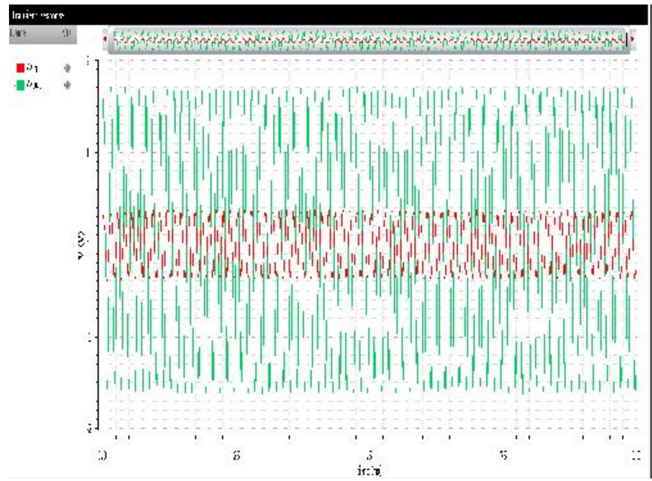

Figure 4: Input and output voltage waveform of class-A PA

b) Current Waveform

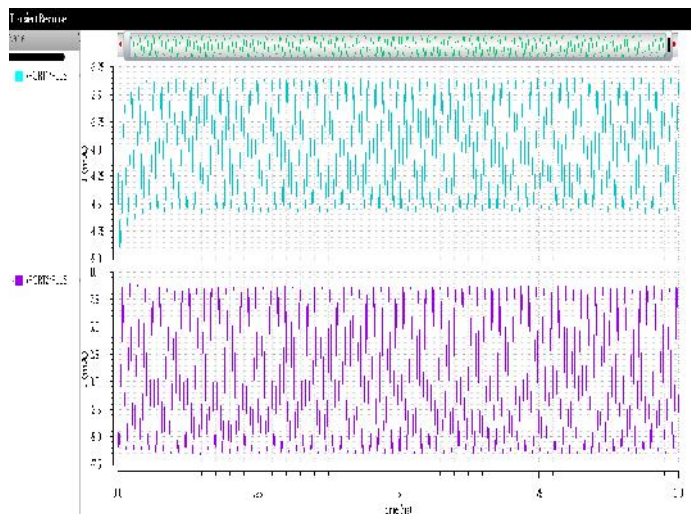

Figure 5: Input & output Current Waveform of Class-A PA

c) Power Waveform

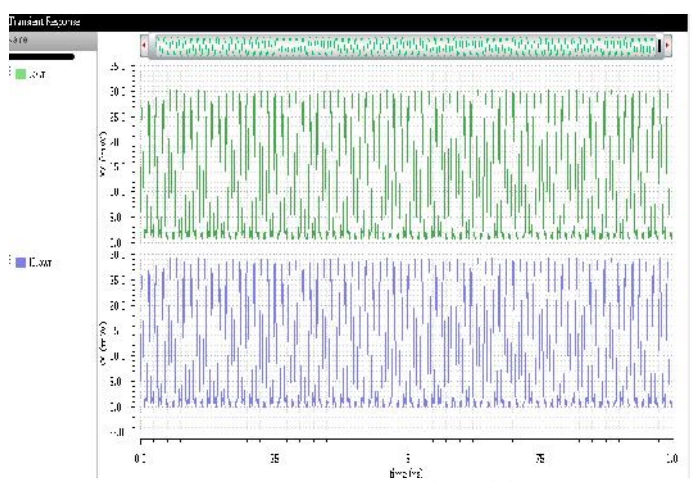

Figure 6: Input & Output Power Waveform of class-A PA

d) Gain and Phase response curve

Gain in dB and phase in degree versus frequency is shown in fig. 7.These response curves are used to determine the gain and phase margin which are used to determine the stability of the circuit.

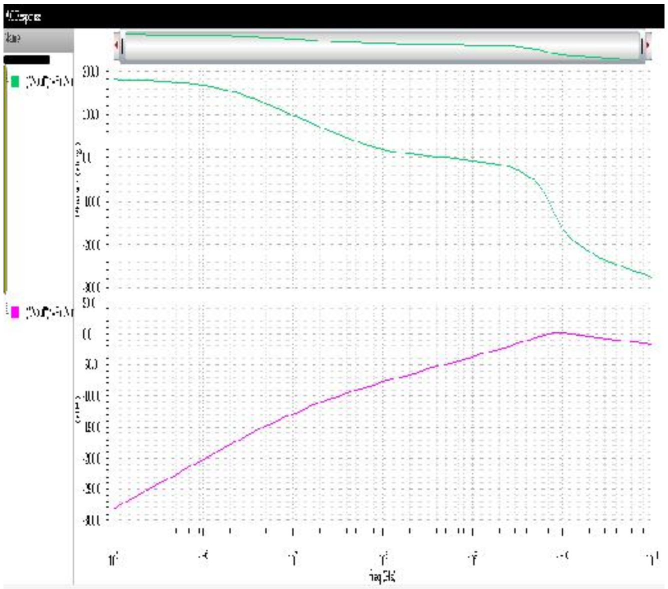

Figure 7: Gain & Phase Response Curve of Class-A PA

C. Schematic of class-E power amplifier

The schematic diagram of class-E power amplifier is designed in 45nm technology by using cadence virtuoso tool is shown in fig. 8.

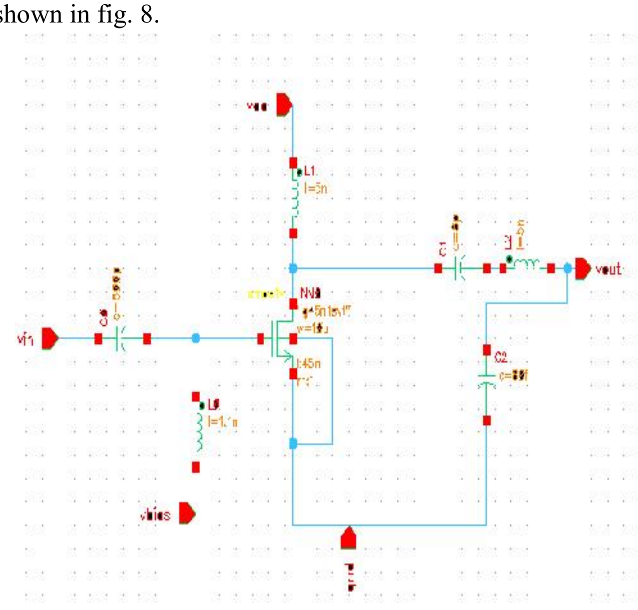

Figure 8: Schematic of Class-E PA

D. Transient Response of class-E power amplifier

a) Voltage Waveform

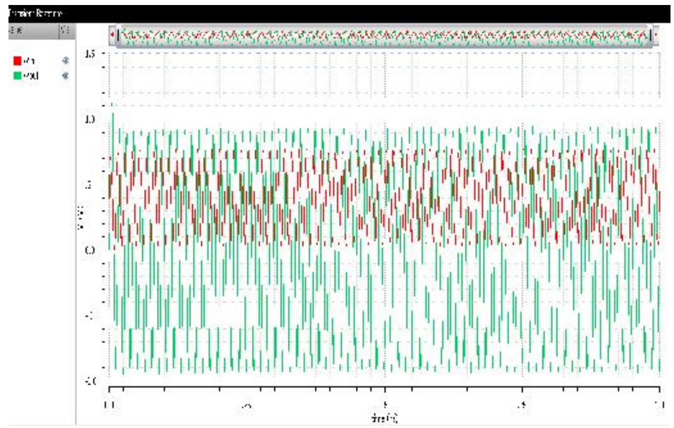

Figure 9: Input & Output Voltage Waveform of Class-E PA

b) Current Waveform

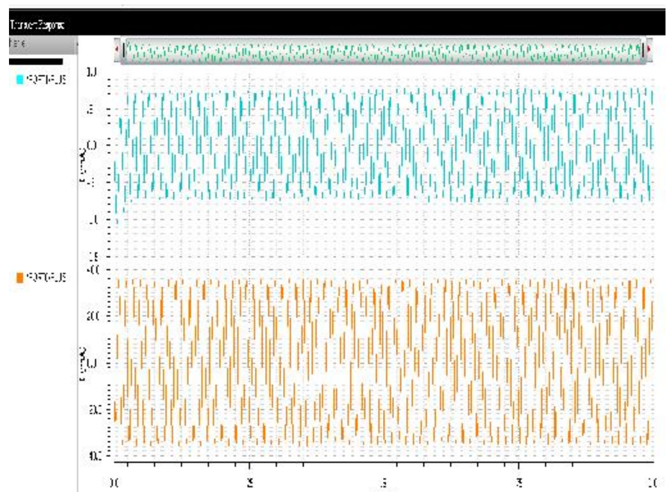

Figure 10: Input & Output Current Waveform of Class-E PA

c) Power Waveform

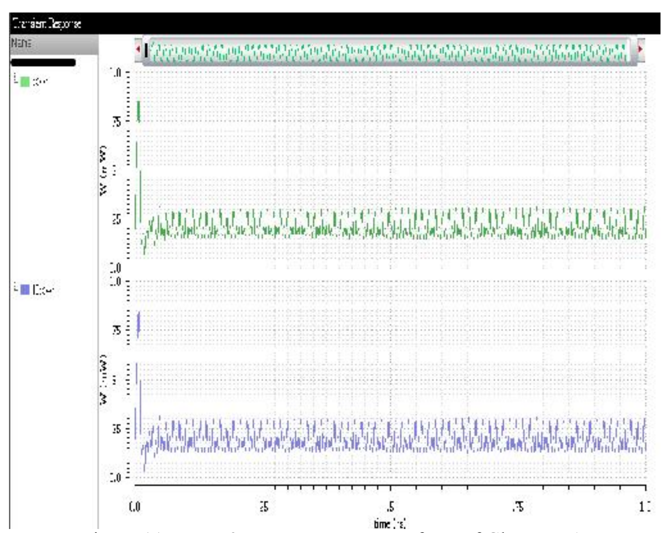

Figure 11: Input & output Power Waveform of Class-E PA

d) Gain and phase response curve

Using gain & phase response curve in fig. 12, gain & phase margin are calculated to determine the stability of the circuit.

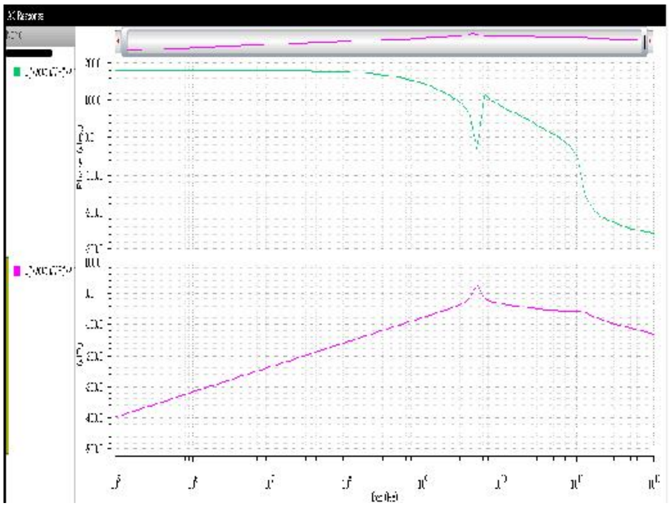

Figure 12: Gain & Phase Response curve of Class-E PA

E. Layout

a) Layout of class-A power amplifier

The layout of class-A power amplifier is created in cadence virtuoso tool using 45nm technology as shown in fig. 13.

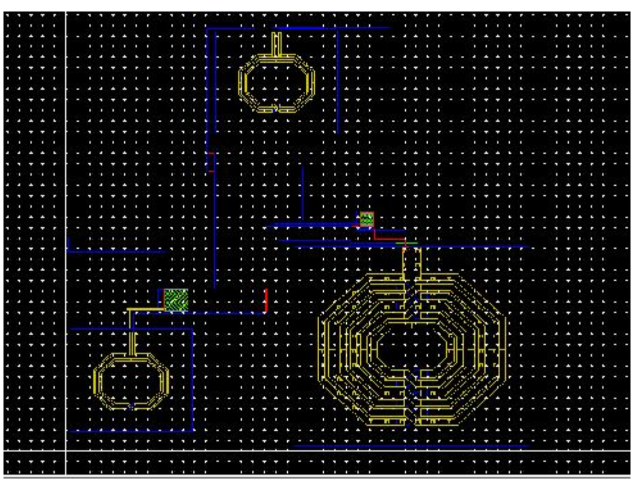

Figure 13: Layout of Class-A PA

b) Layout of class-E power amplifier

The layout of class-E power amplifier is created in cadence virtuoso tool using 45nm technology as shown in fig. 14.

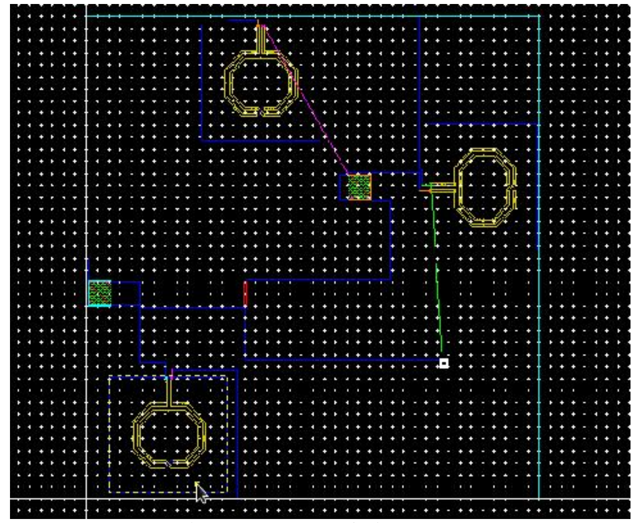

Figure 14: Layout of Class-E PA

III. COMPARISON OF RESULTS

Table 1 Result Comparison of Class-A & Class-E PA

PARAMETERS	CLASS-A PA	CLASS-E PA
VOLTAGE GAIN	13.2dB	8.27dB
CURRENT GAIN	21.54dB	33.9dB
POWER GAIN	17.37dB	21.1dB
OUTPUT POWER	46.74mW	128.96mW
DELAY	135.6fs	1.106ps
AVG O/P POWER DISSIPATION	10.21mW	164.1uW
AVERAGE I/P POWER DISSIPATION	9.402mW	149.7uW
GAIN MARGIN	1.55dB	70.24dB
PHASE MARGIN	61.63°	156°
STABILITY FACTOR (K_f)	34.847	7.43
STABILITY	MORE STABLE	LESS STABLE

IV. CONCLUSION

Two classes of power amplifier that is class-A and class-E are fabricated at 76GHz frequency and in 45nm CMOS technology. The performance of class-A & class-E power amplifier is compared in terms of performance parameters like output power, power gain, Stability, delay and power dissipation. From analysis, it is concluded that, class-E power amplifier provides higher output power, lower power dissipation, higher power gain but lower stability and delay as compared to class-A power amplifier.

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