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Wideband Class-B RF Power Amplifier Circuit Design Using CCMOS Pair

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Abstract - *The wide frequency band RF power amplifier can be achieved with low power consumption on an integrated chip with the help of advanced CMOS technology using high deep scaling. Wide band Power amplifier (WPA) is play the major role in wireless communication system. To achieving the maximum frequency band of power amplifier, we used new innovative pair (CCMOS Pair). This type of amplifier is suitable for wideband applications like Wi-Fi, wireless communication, mobile communication, large signal amplifications and ZigBee etc. based on radio frequency. The designed circuit of wideband power amplifieris simulated on 180 nm cadence virtuoso tool. The simulation results show the wide bandwidth up to ZHz and flat top response with fast switching operation.*

Key Words: *Class B Power Amplifier, CCMOS Pair, 180nm CMOS Technology.*

1. INTRODUCTION

The Radio Frequency Communication system has demanded with high performance parameters from last one decade. Mostly used areas for communications are 5G communication system, Wi-Fi, Biomedical fields, Milliwavecommunication, mobile communication, with fast data operationsandhigher efficiency. The power amplifier directly affects the efficiency of transmitting signals; therefore, wideband power amplifier with low cost and high efficiency is required in the advanced technology of communication system. Standardization of communication demands the durability, Integrated circuits, power conservation and better performance of building blocks of communication system. It is very complex for designers to design and develop the new technology. In last few years ago, communication can be held only with audio, but today audio and video both are required simultaneously. It has a similar importance to connect with digital world. Global positioning system in every field of transmitting and receiving signal, Mobile products, Low range Bluetooth system, satellite communication, Wire-less Local area network and some of the other advanced features will increase people interest in advanced technology and also change the lifestyle of living things. [1] The major parameters to measure the performance of power amplifier are output power, gain, power added efficiency, harmonic distortion, noise and power consumption etc.

1.1 Parameters

a) Output Power

Power at the output terminal of power amplifier should be high for proper communication. It is defined as the active power delivered on the output load (antenna) with fundamental frequency. Instaneous output power ($P_{out\ (ins)}$):

$P_{out\ (ins)} = V_{out}(t) * I_{out}(t)$ ----------(1)

$P_{out} = Vo^2(max) / 2R_{(Load)}$)----------(2)

or

$P_{out} = Vo^2(rms) / 2R_{(Load)}$)----------(3)

a) Gain

The gain of any system has major parameters. It is the ratio of the output power of the system and the input power of the system. This parameter is usually expressed in decibel (dB).

Gain = (P_{out} of the system) / (P_{in} of the system)

a) Efficiency

A main parameter of the power amplifier is the efficiency. This parameter directly affects on the talk-time in handheld communication devices. It has a significant impact on the electricity bill in base station Power Amplifiers. We can measure the efficiency of power amplifier in term of

a)- Drain Efficiency (DE) = P_{out}/ $P_{cons\ (DC)}$

b)- Power-Added Efficiency (PAE)

= P_{out} - P_{in} / Total $P_{cons\ (DC)}$

Moreover, the total DC power consumption includes the DC power consumed at the drain, and the total DC power consumed by all other amplifier stages (A1 and A2). Power amplifier is most important and fundamental block of transmitter side of transceiver. It is the last most part, which deliver the radio frequency signal to the antenna. There are some of the issues related to power amplifier.

- Current Consumption
- Power Dissipation
- Supply Voltage

Like applications WLAN, satellite, Radar communication these applications require considerable power. It is very challenging task to obtain high values of performance and low power consumption. From the energy consumed by transceiver most of the part required only for power amplifier. In certain cases, PA implemented aside from rest of transceiver to get better performance but it will be more expensive, such as GaAs and SiGe, instead CMOS technology efforts can be more affordable in cost. Mainly high output power amplifier can be classified into two groups:

Switched Mode Power Amplifier (A, AB, B and C).

Non-switched Mode Power Amplifier (D, E, F)

In the non-switching amplifiers compromise is there between linearity and efficiency where in order to increase efficiency the linearity should be sacrificed. In other way the linearization techniques are available separately. Classes can be differentiated due to their conduction angle. With the decreasing the conduction angle the power dissipation also get decreased refer to the active devices. Switching amplifiers base their functioning in switching the active devices between the “ON” and “OFF” state, the voltage and current waveforms will be complete out of phase to reduce.

Different types of classes of power amplifier are as follows in the following table 1.1

Table 1.1 Performance of Different power Classes

CLASS	MODES	Conduction angle	Max. Efficiency	Linearity
A	Current Source mode	100%	50%	Good
B		50%	78.5%	Moderate
C		< 50%	100%	Poor
D	Switch mode	50%	100%	Good
E		50%	100%	Good
F		50%	100%	Good

b) Advantages of Biasing

Gate bias is used to maintain constant gate-to-source voltage, VGS to maintain the stability.

1. Biasing will be used to supply the required current at gate to maintain the transistor at operating region.

2. To stabilize the device in case a negative resistance appears in the gate at any frequency where the device has apositivegain.

3. To filter the signal, the products and the harmonics generated by the device input from low to high frequencies without affecting the device input matching circuit.

The topology used in this design is single ended with 2 stages for getting gain as high as possible. It is constituted with the actives components and blocks as shown in figure 2 to maintain the proper biasing conditions and the input and output impedance matching of 50 Ω will help to transfer maximum power at the output. Functioning can be done with the assumption of for the input power provided so that active devices get excited by certain waveform at certain frequency band. Ultimately the energy delivered to output to pass the amplified signal with high output power by the consideration of efficiency.

1.2 Complementary Compound MOS Pair (CCMOS Pair)

This complementary compound pair using MOS has some major advantages than the other pairs(like: Darlington Pair and Sizilai Pair). It is a innovative combination of two NMOS and two PMOS transistor. It is connected as a structure of Darlington structure to produce more required characteristics of MOS transistor with a higher current gain and voltage gain useful in wideband communication system [5]. The block diagram of complementary compound MOS pair is shown in below Fig.1. This innovative CCMOS pair is designed to enhance the band of the amplifier with very low power consumption and boosting gain of the power amplifier with suitable value of W/L ratio of PMOS and NMOS transistor used for wide high frequency communication system as a output device. [6][7].

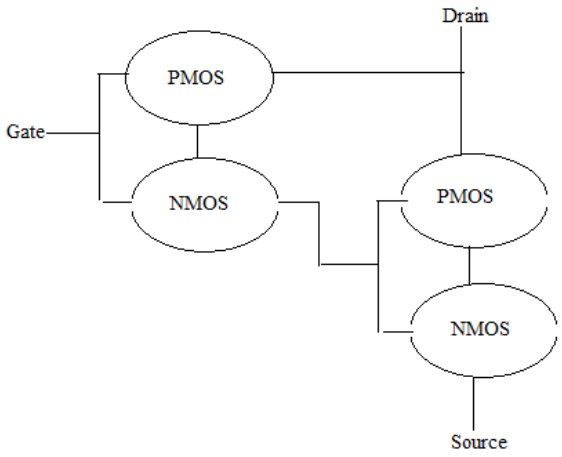

Fig. 1 Block Model of CCMOS Pair as a NMOS transistor

2- PROPOSED CIRCUIT OF POWER AMPLIFIER

A distortion measured by nonlinearity characteristics of power amplifier can be eliminated or make negligible by using complementary Compound MOS pair [8][9]. This is a new innovative pair. This new pair can be used as a inverter. Here when two CCMOS pair are connected in series having an ac input signal biased as a voltage divided method by using proper value of R_1, R_2, R_3 and $R_4$with load at 100 KΩ shown as a proposed circuit in fig (2). The voltage divider biasing provides wide band of operating frequency. The wide band of frequency can be increase by proper value of inductor and R_L as an output load of power amplifier. The variation in frequency bandwidth the value of inductor (minimum pH) and the value of resistor (maximum MHz) is shown in following fig (2). When the value of inductor is varies between the 1 pH to 10 pH with high

output load (10 MΩ) then the maximum low cut off frequency is 20.25KHz and high cut off frequency is 504.7 ZHz shown in fig-4. While the designed power amplifier circuit give the band in KHz. It is very low as compare to proposed circuit.

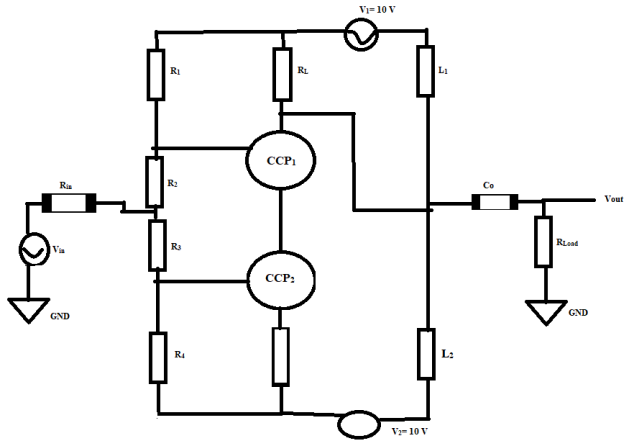

Fig:2 Circuit Diagram of Proposed Class-B power amplifier Using CCMOS Pair

3- SIMULATION RESULTS

The proposed circuit for the class-B power amplifier is simulated by 180nm cadence tool. The AC analysis of proposed circuit produce the wide band of frequency. It is specialized for ultra wide frequency band KHz to ZHz shown in following fig (3). This is the major advantage of proposed power amplifier. From the fig (3), we can analysis the value of bandwidth at 3dB point with the variation in output load and inductor.

Fig: 3 AC analysis of proposed Class-B Power Amplifier

This proposed power amplifier also provides high output power with high efficiency at low input supply. Therefore, it is very useful to drive the output stage in any amplifier system.

Table: 1.2 Comparing Analysis with Previous Designed Power Amplifier

Propo-sed work	Class for Power Amplifier	Wide Frequency Band	Output power [dBm]	Supply voltage [V]	CMOS Techno-logy
This work	B	20.25KHz-504.7ZHz	14dB	2	180nm
[7]	EF	2.5 GHz	20	2	130nm
[8]	F	1.7 GHz	23	3	130nm
[9]	E	2.4 GHz	20	3	130nm

CONCLUSIONS

The class B will give the improved results by consideration of all the parameters. The frequency of 20.25KHz-504.7ZHzgive the wide range of power amplifier to work for different application at this band. In Radar, ZigBee, Wi-Fi, Bluetooth, WLAN, and mobile communication and in medical, defense has wide applications of power amplifier can be operable at this range of frequency. The output and input impedence matching will give better results with the flat top response of current and voltage waveform of CCMOSFET. Fast switching action with class B gives very low power dissipation.

FUTURESCOPE

The proposed work in the field of power amplifier can be done in future to more extended wide band with high output power than present. It can be improve by using the high Q- CMOS inductor in place of passive inductor. The linearization techniques can also be integrated on same die with this proposed work.

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BIOGRAPHIES

Shiksha Jain was born in Aligarh (UP), India in 1984. She received the B.Tech degree in Electronics & Communication Engineering from UP Technical University, Lucknow, U.P. India in 2005, M.Tech degree in Digital Electronics from Gautam Budh Technical University, Lucknow, U.P. India in 2011, pursuing Ph.D in Electronics from Dr. Rammanohar Lohia Awadh University,U.P. India from 2018. Currently she is an assistant professor and head of the department of Electronics & Communication Engineering, Institute of Engineering and Technology,r Dr. Rammanohar Lohia Awadh University, India. His research interest includes microprocessor, VLSI Design, Digital system and Electronics Circuit.

Professor Raj Kumar Tiwari was born in Faizabad (UP), India in 1960. He received B.Sc and M.Sc degree with scoring highest marks and awarded by Gold Medal in Allahabad University. He qualified JRF (CSIR) and also obtained SRF (CSIR) in 1984. He obtained P.hd degree from Dr. RML Awadh University in Physics. He has placed on high positions like Former Director of I.E.T, Ex. Dean Faculty of Science, Ex. HOD in Department Of Physics and Electronics of Dr. R.L.A University Ayodhya. He has published more than 86 Research Papers in Journal and International/National Conferences. 13 Ph.D research scholar has awarded under his supervision. Currently he is working as a Professor in Physics and Electronics Department and Dean Student Welfare of Dr. Rammanohar Lohia Awadh University Ayodhya.