dB - Linear Variable Gain Amplifier with Addition of Diode Connected Load

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Abstract— In this paper, a CMOS linear-in-dB variable gain amplifier (VGA) is presented. Based on the diode connected load technique which improves the gain range, a 108.77dB(–68.67dB to 40.10dB) continuous gain range is achieved with a single-stage structure. Simulation results show that the VGA core consumes of power consumption 0.6uW from a 1V supply with 0.04 dB gain error.

Keywords– CMOS, Variable gain amplifier (VGA), automatic gain control (AGC), dB-linear, Diode connected load, Gain range, Detector, Gain error.

INTRODUCTION

Variable gain amplifiers (VGAs) are indispensable blocks in modern wireless communication systems such as Bluetooth, WLANs, and UWB. Variable gain amplifiers (VGAs) are an important building block of wireless communication systems. The main function of a VGA is to provide a fixed output power from a large different input signal level, increasing the dynamic range of the entire system.

The dB-linear gain characteristic is required for the VGA to maintain a uniform loop transient response and settling time in an automatic gain control (AGC) loop [1] and to prevent a resolution problem of control voltages for a wide variable gain range. For most applications of VGAs, the dB-linear characteristic should be accurate across a large signal range with a small gain error [2], [3].

Although many techniques have been employed to generate the exponential function, these techniques require complex circuitry with extra chip areas [4]–[7].]. One of the critical issues in dB-linear VGA design is building a dB-linear gain characteristic.

With a bipolar junction transistor (BJT), a dB-linear VGA can be easily designed using its exponential characteristic [8]–[10]. However, using MOS devices, it is difficult to obtain a dB-linear function with the inherent square-law and linear characteristics. Although a dB-linear VGA using a MOS device in subthreshold region has been reported [11], it can be used to limited applications owing to its large noise contribution**.** VGA with current squiring technique introduces a single stage CMOS VGA with continuous exponential tuning characteristics, it proposes a new structure to extend the decibel-linear gain range [12].

Gain error compensation technique to provide accurate exponential approximations over the small and large gain ranges of the dB-linear VGA [13]. In this paper dB- linear VGA with addition of diode connected load is presented which introduces improved performance as compare to VGA with gain error compensation technique. Proposed method reduces power consumption without use of any additional circuits, resulting in a robust VGA. The approximation function of the VGA is very accurate across a wide dB-linear range owing to the proposed diode connected load technique. The dB-linear gain is linearly controlled by the gate bias of the control loop circuits, which is very simple.

Variable Gain Amplifiers are used in automatic-gain-control (AGC) amplifiers as feedback loop shown in figure 1.Where the amplitude of the output signal is kept constant for all input signal levels.

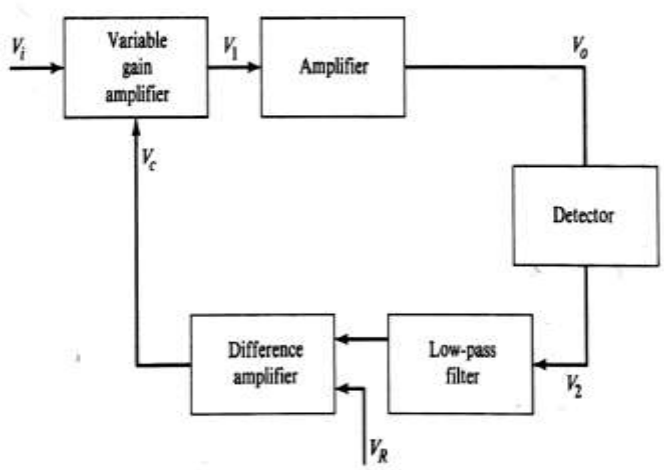

Fig.1. Diagram of AGC

PROPOSED METHODOLOGY

In this paper dB- linear VGA with addition of diode connected load is presented**.** A VGA provides a means of amplifying such signals, with less distortion or saturation, and can be used as the controlled element of an Automatic Gain Control (AGC) circuit in a receiver, or as the controlling amplifier in a Timed-Gain-Control circuit of an Ultrasound system. The load of differential pair need not be implemented by linear resistor so it is desirable to replace resistor with MOS.

the main reason in this M3, M4 are always in saturation region .Because the drain and gate have the same potential MOS is three terminal device which can be used as a resistor (two terminal device) by shorting the gate to the its own drain. Resistor takes more area & noisier so that resistor is replaced by mos. the basic differential amplifier with diode connected load is shown in figure 2. Voltage gain is A_{v} is given by

$$A_v = -g_{mN} (g_{mP}^{-1} || r_{ON} || r_{OP})$$

$$\approx - (g_{mN}/g_{mP})$$

Where subscript N and P denotes NMOS and PMOS, respectively.

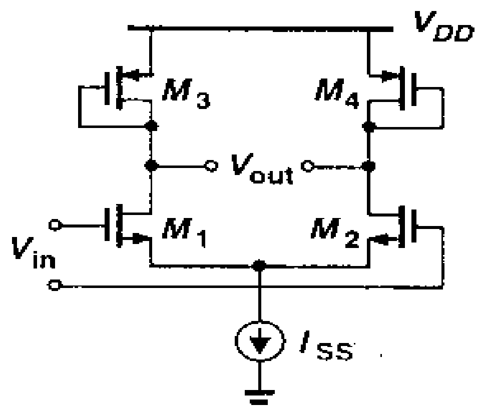

Fig.2. Basic differential amplifier with diode connected load

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$A_v \approx -\sqrt{[\mu_n (W/L)_N / \mu_p (W/L)_P]}$

A variable gain amplifier is a special kind of amplifier whose gain can be dynamically controlled in 'real-time' by an externally applied control voltage. In its simplest form, it can be visualized as an amplifier with an electronic gain control. Proposed circuit of VGA is shown in fig. 3. Where N1, N2 is the n-type differential input pairs. Control voltage is applied at the gate of N3 MOS, which controls the gain of device.

Three terminals MOS is in saturation region act as amplifier and in linear region act as a resistor. Become two terminal devices and in saturation region it work as resistor. P1 and P4 are two terminal devices which are connected at load side. Proposed circuit is operated at very less power supply and provides large dB- linear range with less power consumption [14].

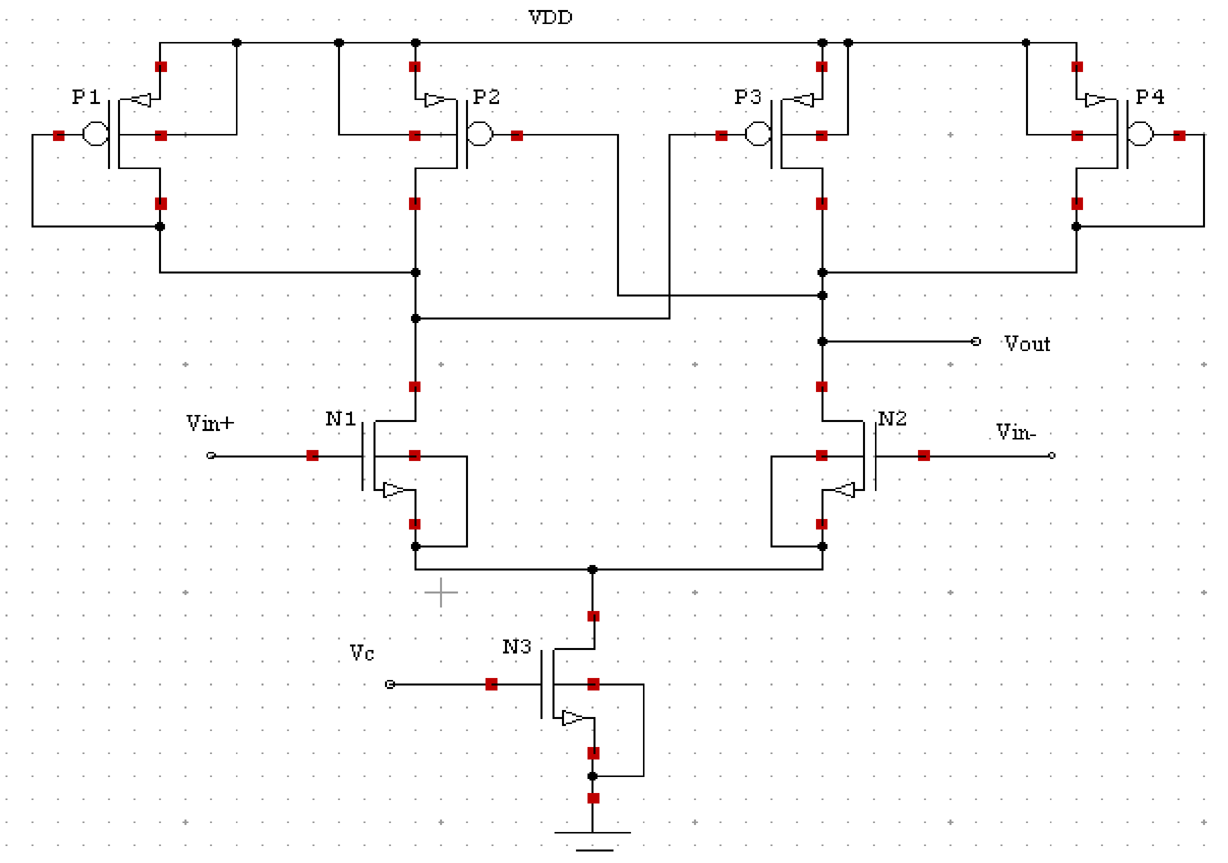

Fig.3. Prorposed diagram of VGA

SIMULATION AND RESULT

The dB-linear VGA was fabricated using a 45-nm CMOS process. The power consumption of this VGA is 0.6(uW) and require less area at 1v power supply and having 96 (dB) dB-linear ranges. Proposed VGA can boost dB-linear range with less gain error as compare to gain error compensation technique. Simulation summary is shown in table I

Table I
Simulation result summary

Design	[13]	This work
Gain range (dB)	-13 to 63	–68.67 to 40.10
dB-linear range (dB)	50	96
Gain error (dB)%	0.5	0.04
Supply (V)	1.2	1
No of stage	3	1
Technology	65nm	45nm
Current consumption(without buffer)	1.8mA	0.6uA
No. of MOS(with buffer)	26	8
Gain bandwidth (MHz)	14.8	58.53
Power consumption	3.84(mW)	0 .6(uW)

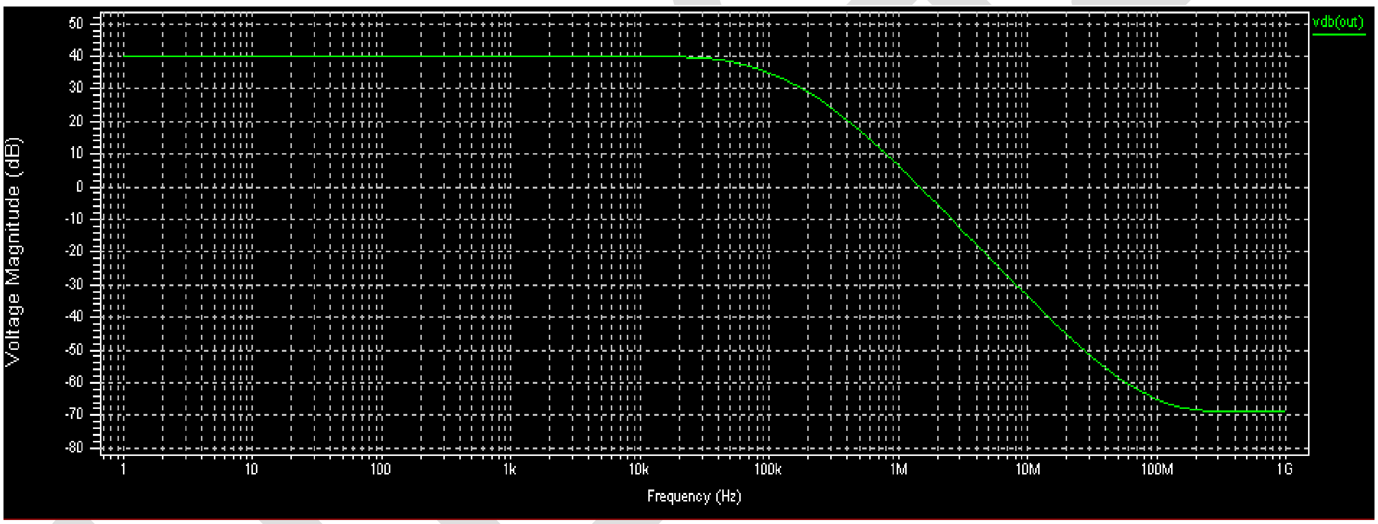

Fig.4. gain (dB) versus frequency (Hz) graph

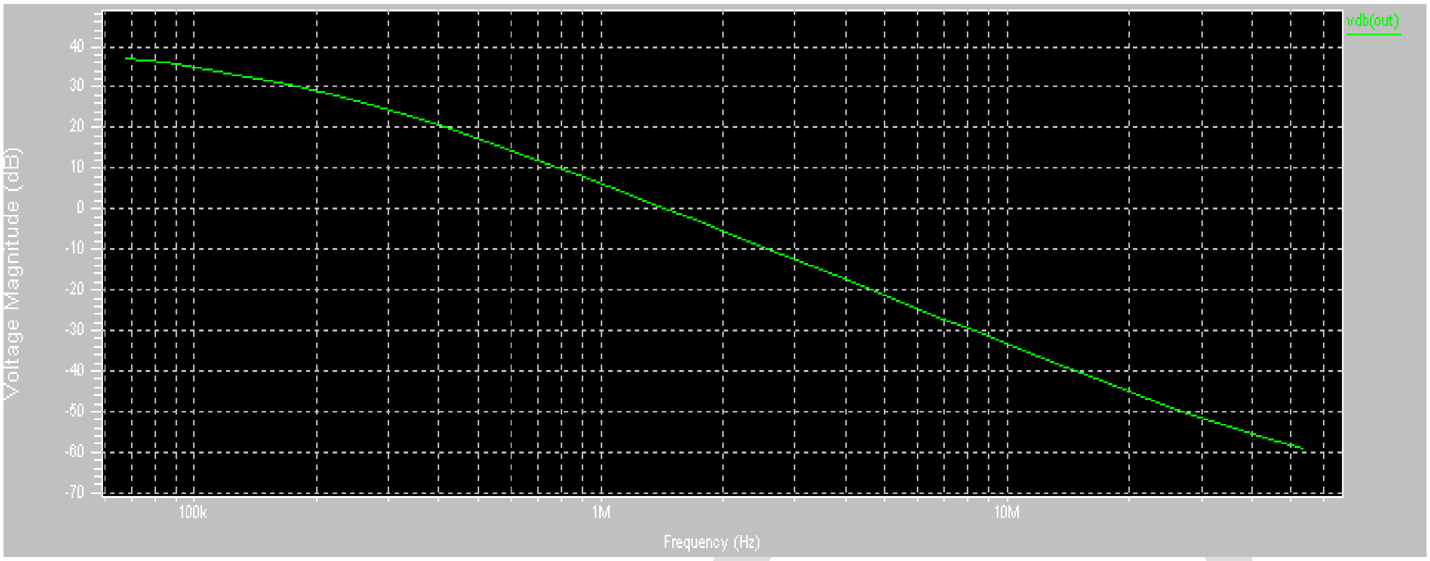

Fig.5. Measured gain of dB –linear VGA at 67.78 KHz to 58.53MHz

CONCLUSION

In this paper, we introduced a diode connected load method for a dB-linear VGA. The proposed approximation does not require an extra circuit for generating the exponential function and it drastically reduces design complexity and chip area. Moreover, the dB-linear gain can be controlled easily using the gate bias. Because of the simple control method, this VGA is robust to the process variation. The VGA based on the proposed method can be fabricated using any VGA that has a linear gain characteristic. by using of diode connected load ,we achieved a dB-linear gain range 96dB within 0.04dB gain error.

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