REVIEW ON VARIABLE GAIN AMPLIFIERS FOR AUTOMOTIVE RADAR APPLICATIONS

[1]Arshi Dhiman, [2]Mr. Bipan kaushal
[1]M.Tech Student, [2]Assistant Professor
[1]Electronics and Communication Engineering Department
[1]Punjab Engineering College (Deemed to Be University), Chandigarh, India

Abstract: Variable gain amplifiers (VGAs) or a voltage controlled amplifiers are signal-conditioning electronic amplifiers that varies its gain depending on a control voltage. They are utilized in various applications of remote sensing and communication equipment. Applications of VGAs include radar, ultrasound, wireless communication and even speech analysis. These applications use VGA mainly to enhance dynamic performance. The idea behind this work is to reduce the number of road accidents by developing in the automotive radar fields multichannel sensor systems which give 3D vision to the car so that the driver is able to detect collisions. These sensor systems employ receivers having variable gain amplifiers (VGAs) as one component of the receiver chain. In this work, design of variable gain amplifier for automotive radar applications has been implemented taking into account linearity, noise and gain trade-offs.

Index Terms – *Variable Gain Amplifiers (VGA), noise, linearity, gain, Analog Variable Gain Amplifiers (AVGA), Digital Variable Gain Amplifiers (DVGA)*

I. INTRODUCTION

Variable gain amplifiers (VGAs) are signal-conditioning amplifiers with electronically settable voltage gain. They maximize the dynamic range of the overall system and maintains sufficient signal-to-noise ratio for a specific application. VGAs reduce cost and save space, but they also offer better performance in terms of noise, distortion and power consumption.

Depending upon the nature of the gain control signal, the Variable Gain Amplifiers (VGA) can be divided into two categories:

- Analog Variable Gain Amplifiers
- Digital Variable Gain Amplifiers

Digital VGA's gain is controlled with digital control signal and that of analog VGA is controlled with an analog control signal. In general, digitally controlled VGA's gain is controlled by binary weighted arrays of resistors or capacitors and the analog VGA's gain is controlled by transconductance or resistance stages [5]. The analog variable gain amplifier (AVGA) is compact in size as compared to the digital variable gain amplifier (DVGA) but in the digital variable gain amplifier (DVGA) different parameters of the gain control could be observed.

VGAs can be found in communications, cable TV, medical equipment, and industrial applications. In medical and industrial scanner applications, VGA is used in specialized circuits called time gain controls (TGCs), which compensate for attenuation in the medium being probed. In medical ultrasound systems, echoes from structures deep in the body must be amplified more than echoes close to the skin [1][2]. In communication systems, they play an indispensable role in receivers by controlling output signals from the filter to the required input signal level of the ADC thus providing the largest signal-to-noise ratio to the ADC stage and improving the overall dynamic range of the receiver.

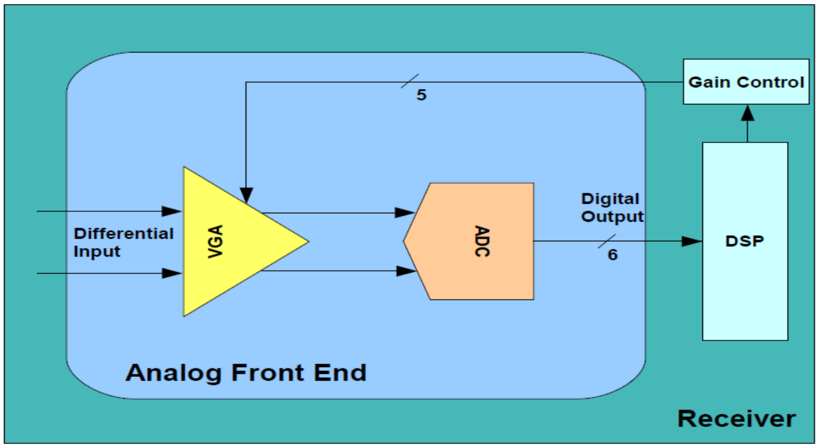
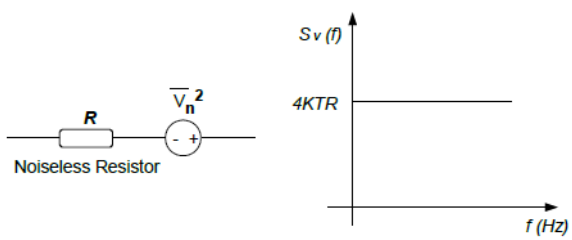


Fig:1. VGAs used in analog Front End

II. DESIGN CHALLENGES OF VGA

1. Noise: The noise is an unwanted signal, which degrades the performance of the system. It limits the signal level which could be processed by the system with acceptable quality. The noise is important for the analog design because it provides tradeoff between power dissipation, speed and linearity. The analog signal in VGA is corrupted by two types of noise that is electronic device noise and environmental noise [7]. The electronic device noise is generated by resistors, transistors and other electronic devices. The environmental noise is random disturbance, which is experienced by the electronic circuit through the supply lines or the substrate.

(i) Resistor thermal noise: It is generated due to the random motion of the electrons, which produces the fluctuation in the voltage across the resistor even in zero average current. The spectrum of the thermal noise and the thermal noise generated by the resistor can be modeled, by a voltage source in series as shown below.



(a) Equivalent resistive thermal noise source (b) Spectrum of resistor thermal noise

(ii) MOSFET thermal noise: It is generated mostly by the channel. The noise model for a long channel device is shown below.

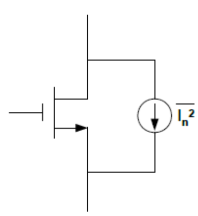


Fig:2. Long channel MOSFET, thermal noise model

(iii) Flicker Noise: The interface between the gate oxide and the substrate consists of many dangling bonds at extra energy state. The charges moving at this interface is trapped randomly and released, causing the flicker noise. This is believed that the trapping is not the only phenomenon for the flicker noise. The flicker noise is modeled by a series voltage source at the gate terminal of the MOSFET.

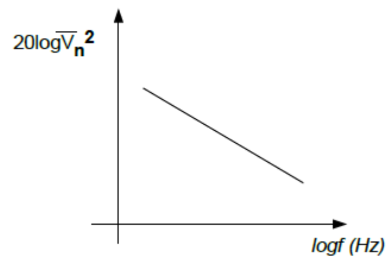


Fig:3. Flicker noise spectrum

2. Non-Linearity: As the signal amplitude increases, the non-linearity comes into play. At the small signal amplitudes, the output is approximately exact replica of the input but as the signal amplitude increases from certain limit, the amplifier exhibit saturation, which results in the non linearity. For higher linearity of the multi stage amplifiers, the gain of the first stage should be low but higher the gain of the first stage, lower the noise figure [2]. So, there is a trade off in setting the gain of the multistage amplifiers.

The principle of the linearization is to reduce the gain dependency of the amplifier on the input amplitude, by making the gain independent of the bias current. The simplest method for linearization is the source degeneration which utilizes a linear resistor at the source terminal. This resistor reduces the swing at the gate to source, making the input/output characteristics more linear.

3. Gain variation range: It is the difference between the highest gain and the lowest gain that a VGA can provide. The gain variation range should be large enough to cover the whole possible input signal range. Large gain variation range can be realized in a single stage, or by cascading multiple stages. Cascading multiple stages usually result in higher power consumption, larger die area, poorer linearity and noise performance [9].

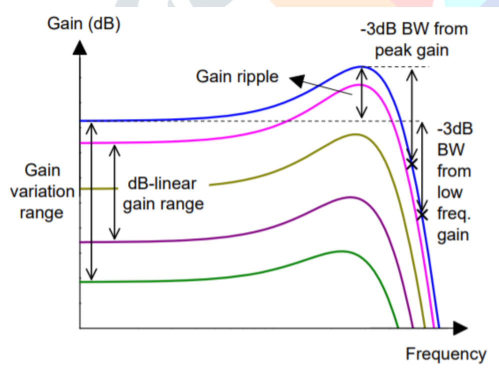


Fig:4. Gain characteristic versus frequency curve

4. Process Variation and Temperature: Monte Carlo simulation is commonly used for the performance under various process conditions, and corner simulation is used for the extreme case. If a VGA operates well across all corners, then the final yield is close to 100%. Performance variation across various temperatures is also desirable to be as small as possible, such that the VGA is able to operate under various conditions and the robustness is improved [8]. The VGA design is best to be process variation insensitive as well as temperature insensitive to improve the yield and reliability, which in turn reduces the cost of mass production.

III. LTERATURE SURVEY

Otaka et al., 2000 [1] proposed a VGA, which consists of the conventional signal-summing VGA and a control signal converter (CSC) for gain compensation. Low-noise performance is required around the maximum gain in RX-VGA. A differential amplifier without emitter-degeneration resistor gives a low noise figure (NF). Temperature compensation (TC) for the gain is required, because a transconductance of the differential pair depends on temperature, so a Windlar current source is used for the gain compensation.

Duong et al., 2006 [10] implemented a VGA that offers wide bandwidth and gain variation characteristics for ultra wideband system applications. The proposed VGA is a compact one that combines a cascade input stage and bandwidth extension loads to obtain a wide bandwidth leading to low power consumption and the conventional VGA is the one without any bandwidth enhancement technique for the same supply current.

Chen et al., 2009 [7] reported that the design of low-noise amplifier (LNA) for DVB tuner needs wideband operation and larger dynamic range besides low noise and high linearity, so a variable gain low-noise amplifier with noise and nonlinearity cancellation for Digital Video Broadcasting applications was implemented. This application uses a resistive-feedback inverter integrating feed-forward noise and nonlinearity cancellation to achieve wideband low-noise and high-linearity property, while combining the gain control scheme to reach more dynamic range.

Huang et al., 2012 [8] proposed the VGA architecture capable of handling higher input power, having a relatively wide bandwidth, smaller size, and a continuous control curve by a self-biased differential amplifier with a dynamic current source to provide gain and linearity. This topology was implemented to optimize for linearity, bandwidth, and linear-in-decibel controllability making it suitable for the amplitude pre-distorter in an analog-predistortion PA system.

Lu et al., 2016 [9] proposed a Cell-Based VGA to implement a Bandwidth Compensation Technique to control gain with smaller bandwidth variation. Gain control can be achieved by feedback resistance introduced in the modified Cherry Hooper amplifier. However, with extra zeros and poles introduced by the feedback loop, the bandwidth depends on the bias current and feedback resistance value. An exponential voltage to current converter is embedded to achieve dB linear characteristics.

Francesco Belfiore et al., 2017 [2] presented the first eWLB packaged low-cost single chip 76-81GHz transceiver with a programmable multichirp FMCW modulator for all the radar applications. Since he felt the need of zero accident road safety, he developed in the automotive radar fields multi-channel sensor systems in order to have a 3D vision around the car. SiGe bipolar technology for single chip radar is the best solution to optimize the performances and to reduce the cost, in order to make sensors more attractive also in cars of lower middle- sized class.

IV. CONCLUSIONS

Maximising the dynamic range of the overall system and maintaining sufficient signal-to-noise ratio for a specific application make VGA a very essential block in communication systems and many other applications but the design of variable gain amplifier is limited by linearity, noise and gain tradeoffs. Although problems exist but VGA with source degeneration has been considered as an attractive approach to optimise the tradeoffs between gain, linearity and noise.

REFERENCES

1. Otaka, S., Takemura, G. and Tanimoto, H., 2000. A low-power low-noise accurate linear-in-dB variable-gain amplifier with 500-MHz bandwidth. IEEE Journal of Solid-State Circuits, 35(12), pp.1942-1948.
2. Belfiore, F., Calcagno, A., Borgonovo, G., Castro, M.G., Pisasale, A., Platania, M., Vinciguerra, M., Alessi, G., Burgio, C., Leonardi, S. and Salomon, A.M., 2017, October. A 76 to 81GHz packaged transceiver for automotive radar with FMCW modulator and ADC. In Radar Conference (EURAD), 2017 European (pp. 143-146). IEEE.
3. Avenier, G., Chevalier, P., Troillard, G., Vandelle, B. and Brossard, F., 0.13$ mu $ m SiGe BiCMOS technology for mm-wave applications. In Proc. 2008 Bipolar/BiCMOS Circuits and Technology Meeting (pp. 89-92).
4. He, L., Li, L., Zhao, D. and Wang, Z., 2016, April. A low-power wide gain range digitally controlled variable gain amplifier with a wide tuning bandwidth for 60 GHz applications. In Wireless and Microwave Technology Conference (WAMICON), 2016 IEEE 17th Annual (pp. 1-4). IEEE.
5. Chen, K.S., Hsu, N.T., Lu, K.C., Horng, T.S. and Wu, J.M., 2009, December. A variable gain low-noise amplifier with noise and nonlinearity cancellation for DVB applications. In Microwave Conference, 2009. APMC 2009. Asia Pacific (pp. 1144-1147). IEEE.
6. Huang, Y.Y., Woo, W., Jeon, H., Lee, C.H. and Kenney, J.S., 2012. Compact wideband linear CMOS variable gain amplifier for analog-predistortion power amplifiers. IEEE Transactions on Microwave Theory and Techniques, 60(1), pp.68-76.
7. Lu, M., Kumar, T.B., Yu, X. and Yeo, K.S., 2016, October. Linear-in-decibel variable gain amplifier design in 0.18 µm SIGE BICMOS technology. In Solid-State and Integrated Circuit Technology (ICSICT), 2016 13th IEEE International Conference on (pp. 116-119). IEEE.
8. Hauptmann, S., Carta, C. and Ellinger, F., 2010. Fully differential variable gain amplifier for 60 GHz applications. Electronics Letters, 46(19), pp.1330-1331.
9. Avenier, G., Diop, M., Chevalier, P., Troillard, G., Loubet, N., Bouvier, J., Depoyan, L., Derrier, N., Buczko, M., Leyris, C. and Boret, S., 2009. 0.13$\mu $ m SiGe BiCMOS Technology Fully Dedicated to mm-Wave Applications. IEEE journal of solid-state circuits, 44(9), pp.2312-2321.
10. Duong, Q.H., Park, T.J., Kim, E.J. and Lee, S.G., 2006, May. An all CMOS 743 MHz variable gain amplifier for UWB systems. In Circuits and Systems, 2006. ISCAS 2006. Proceedings. 2006 IEEE International Symposium on (pp. 4-pp). IEEE.