Book Review:

Low-Voltage Low-Power Analog Integrated Circuits

Edited by Wouter A. Serdijn

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In these days, semiconductor products are integrated within a same die with more complex function components in small scale. It makes possible the emergence of very tiny equipments like hearing aid device, human implant chip, RFID and so on. But, the battery size of mentioned systems will give us obstacle to shrink more. Low-voltage low-power circuit technique will be more valuable to reduce the battery size and keep long operation promisingly. The book includes seven selected papers with guest editorial published in the area of Low-voltage low-power analog circuits. The papers are collected by Wouter A. Serdijn as the Special Issue in 1995.

The first paper, "A High Performance RDS-detector for Low Voltage Applications" by Michiel Steyaert, et al., presents the new topology of the RDS(Radio-Data-System) detector, analog part for an RDS receiver, in low-voltage (1.8V) applications with low-power consumption requirements. The authors use direct conversion with a low-pass filter instead of a band-pass filter to reduce the system components in the digital signal processing. It will decrease the power consumption in a lower operating frequency without the deterioration of performance, even improvement. From the viewpoint of power consumption, this design reduces the power, 60 uW in Opamp and 240 uW in fliter, about 100 times lower than previous RDS detectors, 5 mW in Opamp, 40mW in filter in operating voltage of 5V, in a market.

In second paper "Partial Positive Feedback for Gain Enhancement of Low-Power CMOS OTAs ", written by Rongtai Wang and Ramesh Harjani, it is shown that partial positive feedback is to increase 20dB in the gain and improve 5 times of the bandwidth of CMOS OTAs without any increase in power. The topology of OTAs gives similar functionality but more performance. For a fixed power, the authors use the partial positive feedback to increase effective transconductance of the OTAs instead of input differential pair in the subthreshold region, increasing the ratio of the current mirror in common OTAs architecture ,which has limitations of the reduced frequency by increasing the parasitic capacitance and the static power dissipation of the amplifier, and using adaptive biasing in the subthreshold region. The basic concept is to apply any possible methods for increasing effective transconductance for better performance in the gain and bandwidth of OTAs in the given power limitation.

The third paper,"Parallel Feedforward Class-AB Control Circuits for Low-Voltage Bipolar Rail-to-Rail Output Stages of Operational Amplifiers" by W. C. M. Renirie, et al., presents a set of five class-AB control circuits has been designed to satisfy the low-voltage demand for the operational amplifier, a very commonly used building block in analog circuits. The bipolar output transistors should be connected to the output terminal by their collectors which makes a rail-to-rail output range possible, instead of connecting their emitters in conventional Opamps. The output transistors biased with class-AB control circuits guarantee efficient current consumption in good linearity and high frequency behavior. But, existing bipolar class-AB control circuits for rail-to-rail output stages are complex, using feedback with complexity in high-frequency compensation and suffering from non-linear characteristic. This paper suggests a new set of five simple class-AB control circuits for low-voltage bipolar output stages using parallel feedforward which makes high-frequency compensation possible.

In the fourth paper "Low-Voltage Low-Power Opamp Based Amplifiers", written by Johan H. Huijsing, et al., it is mentioned that amplifiers operating under low-voltage and low-power conditions have strong limitation in dynamic range and bandwidth. The maximum dynamic range is lowered by the lower supply power and thermal noise in resistors. Similar to above paper, input and output stages in promised analog circuit architecture need to process signals from rail-to-rail for obtaining the maximum in the supply voltages of 1.8 V or even 0.9 V. With the dynamic range limitation, the bandwidth of circuits is suppressed by the low bias current of the output transistor and the load capacitance. This limit could only become better by using Miller compensation in a two-stage amplifier and Mulitpath Nested Miller compensation in a three-stage amplifier. The Multipath Nested Miller compensation is also utilized for improving single stages. For example, the authors finally mention the BiCMOS output stage in which a bipolar output transistor with the ultimate high bandwidth is combined with a CMOS transitor with the ultimate high current gain.

In the fifth paper "An Integratable Second-Order Compensated Bandgap Reference for 1V Supply", written by A. Van Staveren, et al., the authors present that the design of a second-order bandgap reference in a new systematic approach is implemented using a linear combination of only two base-emitter voltages, one biased with a PTAT current and the other with a constant current, viable from 1V supply voltage. The key idea of implementing previous bandgap references adds a voltage, proportional to the absolute temperature (PTAT), to a base-emitter voltage to compensate for the first-order temperature dependency. For second-order, a non-linear temperature behavior, the collector bias currents of transistors is used. But, in a systematic design method several design stages on different hierarchical level effect on adjusting more detailed and dependent on the technology, after determining the dominant parameters at the highest level of the bandgap reference considering ideal devices. Also, the authors take an account of the reverse Early effect as the extra temperature dependency. The implemented circuit show an output voltage of about 194 mV and the mean temperature dependency 1.5 ppm/ °C in the range of 0 °C to 100 °C.

The sixth paper, "An Analytical MOS Transistor Model Valid in All Regions of Operation and Dedicated to Low-Voltage and Low-Current Applications" by Christian C. Enz, et al., presents that for the design and analysis of low-voltage and low-current analog circuits, analytical MOS transistor model is introduced using all continuous large and small signal variables such as currents, transconductances, intrinsic capacitances, non-quasi-static transadmittances and thermal noise in all regions of operation. The characteristics of transistors should be well defined for analog designers to use for simulation in performance observation of their designs. Therefore, the authors derive the device model to low-voltage and low-current circuits with the behavior from subthreshold operation to large currents continuously.

The last paper, "Design Principles for Low-Voltage Low-Power Analog Integrated Circuits" by Wouter A. Serdijn, et al., is shown that the reason to choose current than voltage as the information-carrying quantity in low-voltage and low-power design constraints is to improve the transfer quality. The transfer quality is influenced by stochastic error from inaccuracies in the input-output relation, and systematic errors from network imperfections. The authors mention design strategies for the reduction of these errors are usually not consistent with power dissipation, voltage range and current range in whole design process. With including whole consideration, current is become more favorable than voltage as the information-carrying quantity and indirect feedback is chosen in a low-voltage and low-power designs.

The book presents materials related to the low-voltage and low-power circuit designs from the system level, the first paper, to the device, the sixth paper, with the source of a suitable information carrier, the last paper. For advanced reader in the analog field, this book is valuable to give them the story of low-voltage and low-power design, what is concern and how to implement using proper techniques. But, there are no explanations of the basic terms and what that means for the beginner in this field. In my opinion, the book includes papers from very well-know authors in RF and Analog fields with providing a short way to high performance in the low-voltage and low-power areas.