



Zen of Analog Circuit Design

By Anand Udupa

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From 2011 till 2013, I taught a course titled **Analog Design for all** which covered concepts starting with MOS transistors and progressed till the design of two-stage amplifiers. The course introduced concepts in a manner that led the student to the **synthesis** of new circuits, not merely their **analysis**. But I still felt that there was a more intuitive way to introduce Analog Circuit Design, one that would bring out the beauty of the subject so that the student could ‘stop and smell the roses’.

But why a ‘Zen of Analog’...?

Because the foundational concepts in Analog closely mirror human relationships! The purpose of this book is to take a simplified and intuitive path to unlock some profound secrets of Analog. The protagonist of this book is Ang-Lao, a medieval monk who brings his insights into the Analog world to solve the challenges in human relationships.

The book addresses a problem statement that much of Analog Circuit Design tries to solve - how do you realize an **ideal buffer**? It starts with the simple concepts of voltage sources and current sources. From the I-V curve of the MOS transistor, we see how it behaves much like a **Voltage controlled current source** (VCCS). The inherent challenge in getting even a simple two-transistor circuit to work is the conflict arising from having two such current source-like elements in series. The **digital inverter** is shown to be one such circuit that can function like an **analog amplifier**, albeit over a narrow range of input voltage. The effect of **loading** on such a circuit is illustrated graphically and is shown as an added challenge in getting it to work in an analog manner.

Having understood the complications involved, we see how through the strikingly simple but immensely powerful concept of **feedback**, one of the two transistors can be modified subtly to make it behave like a voltage source. In that process, we realize our first approximation to an ideal analog buffer. We then see how manifestations of the same concept leads us to the synthesis of a whole

bunch of two transistor circuits - **source followers**, common source amplifiers with **gm-load** and with **diode-connected load**, and **differential amplifiers** . The concepts used in synthesis of such elegant circuits are also extended to the analysis of much more complex circuits, for example, a **Voltage to Current (V2I) conversion** circuit. We introduce the concept of small signal parameters, **gm, gds**, showing the calculations for the gain and output impedance of our circuits, and quantifying how good each of our buffers really are.

The narrative switches between concepts of Electronics and the story of Aman-Ra, an engineer from Medieval Egypt. Struggling with his relationships, his guiding light is Ang-Lao, who teaches him the secret to happy relationships.

For some, this book will signal the end of the fear of Analog. For others, it will be the start of a love story.

Concepts covered

- oI-V characteristics of Voltage & Current sources
- oIdeal & non-ideal sources
- oControlled sources
- oActive and passive elements
- oI-V characteristics of a MOSFET
- oMOS transistor as a Voltage controlled current source
- oDigital inverter as Analog amplifier
- oOperating point
- oCommon source (CS) amplifier
- oEffect of loading on a CS amplifier
- oFeedback
- oHow can you make a MOSFET behave like a voltage source?
- oSynthesis of a CS amplifier with diode-connected load
- oAnalysis of a V2I circuit including an introduction to current mirror
- oSynthesis of CS amplifier with gm-load
- oSynthesis of source follower circuit
- oSmall signal parameters: gm, gds
- oSmall-signal gain and output impedance
- oSynthesis of a differential amplifier
- oSynthesis of an Operational amplifier
- oRealizing the buffer using the Operational Amplifier

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Editorial Review

Review

"This book is a goldmine of insight. Starting with very simple ideas, the book introduces the reader to progressively more complicated circuits, while building on the ideas presented up to that point. It is a testimony to the writer's craft and expertise to have written an entire book where all the essential ideas involve just 2 transistors; and yet there is much left to the reader to reflect upon. The writing helps shape the way the reader ought to think about circuits. There is little doubt that the thought process explained in the book, is at some level, what goes on in the mind of a circuit design expert as they set to analyze/design a circuit."

"Pretty amazing book. Very interesting way of looking at Analog Circuit design through simple stories and real psychological analogies. Thoroughly enjoyed it!"

Users Review

From reader reviews:

William Fiscus:

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