Analog Integrated Circuit Design – Why?

Abstract: What is analog? Everything we see, hear, and perceive in life is analog, from voice, music, and seismic activity to visual perception, voice recognition, and energy conversion and transfer. As a result, all electronic systems must interface with the world via analog electronics. Conforming these functions to today's and tomorrow's relentless demand for small, chip-integrated, mobile, battery-operated devices challenges analog engineers and researchers to design and create smart, robot-like solutions with state-of-the-art accuracy, speed, and extended battery life, which demands and requires training. Examples of the types of applications the field enjoys range from biologically inspired devices (e.g., pacemakers, nanotechnology probes, and so on) and commercial products (e.g., laptops, cellular phones, microsensors, and more) to military hardware (e.g., unmanned aerial vehicles, light-weight electronic equipment, etc.) and space exploration (e.g., remote meters, robots, and so forth). It is impossible to imagine engineering real-life solutions without the help and support of analog microelectronics.

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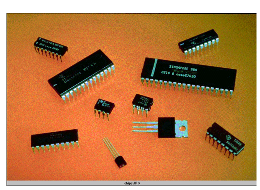


Gabriel Alfonso Rincón-Mora

Georgia Institute of Technology

Rincon-Mora.gatech.edu

Outline

What is the difference between analog and digital *signals*?

Why analog?

What is the difference between analog and digital *IC design*?

What is the design process really like?

Why do I have a *passion for analog IC design*?

What is the difference between analog and digital signals?

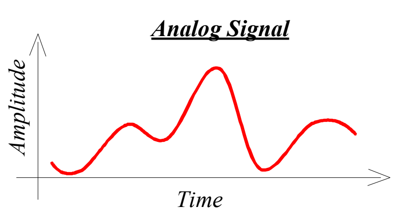
Definitions

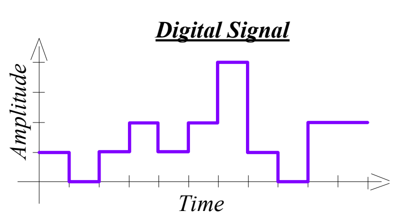
Analog Signal: Continuous over time and space.

→ "Analogous" to the physical signal it represents.

Digital Signal: Sampled at discrete points in time and discrete values (amplitude).

→ Signal is quantized, so it is an approximation.





Infinite versus finite number of states → Analog = Digital + Every point in between.

Why analog?

Fact: Physical signals are continuous in time and amplitude → *Analog*.

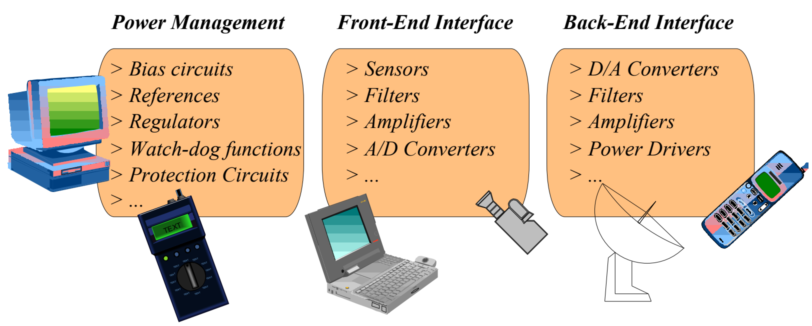
E.g.: Seismic, audio, video, biological, and so on.

But: Digital signals are discrete → *More distinguishable*.

I.e.: More room for error → Higher noise immunity.

So: Interface, condition, and process analog signals,

and *when possible*, convert into and process digital stream.



What is the difference between analog and digital IC design?

Analog Design Process

Specification
* System Design
* Circuit Design
* Component Design
* Circuit Simulations
* Worst-Case Ckt. Simulations (Temp. & Process)
* System Simulations
* Worst-Case Sys. Simulations (Temp. & Process)
* Circuit Layout Design
* Top-Level Layout/Interconnect

Verification
Fabrication
* Device Debug
* Circuit Debug
* System Debug

Digital Design Process

Specification
* System Design

Ckt. = Autogenerated

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* System Simulations

Ckt. Layout = Autogenerated
Top-level = Autorouted
Verification
Fabrication

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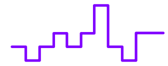
* System Debug

* *Designer's major tasks*

Digital circuit and layout design can be automated with computer-aided design (CAD) tools.

Analog Integrated Circuit Design: Why?

What is the difference between analog and digital IC design?



Trend: On-chip integration → Mixed-signal design.

Digital circuits inject switching noise via substrate, supplies, circuits, and traces.

Trend: 50%–90% of chip is digital and 10%–50% is analog.

Die is mostly digital ∴ Engineers optimize technologies for digital circuits.

Design-Time Syndrome:

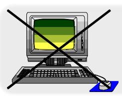
In a 10% analog–90% digital die, 10% analog requires 90% of total design time.

Pass(attempts)-to-Success Ratio: Digital Designs ≈ 1 and Analog Designs ≈ 2–3.

High-performance analog design cannot be automated ∴ No standard cell libraries.

E.g.: Operational Amplifier → Optimizing *all* possible parameters is impossible,

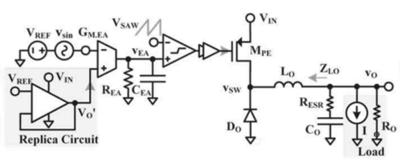
And not all parameters are equally important ∴ Circuit is continually redesigned.



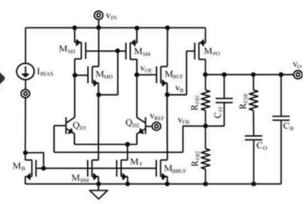
Analog design is difficult, challenging, and always new, so good analog IC designers are always in high demand.

What is the design process really like?

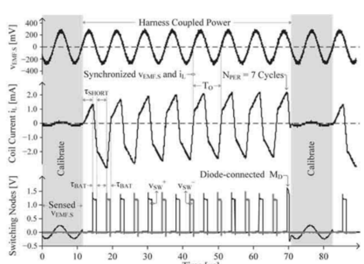
Brainstorm Ideas



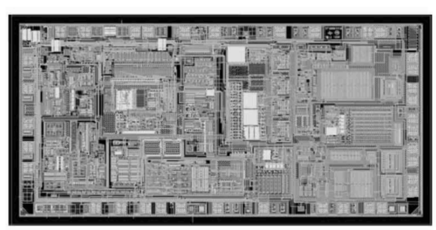
Design Block-Level System



Design Component-Level Circuit



Verify Design (with Simulations)



Design Physical Translation (Layout)

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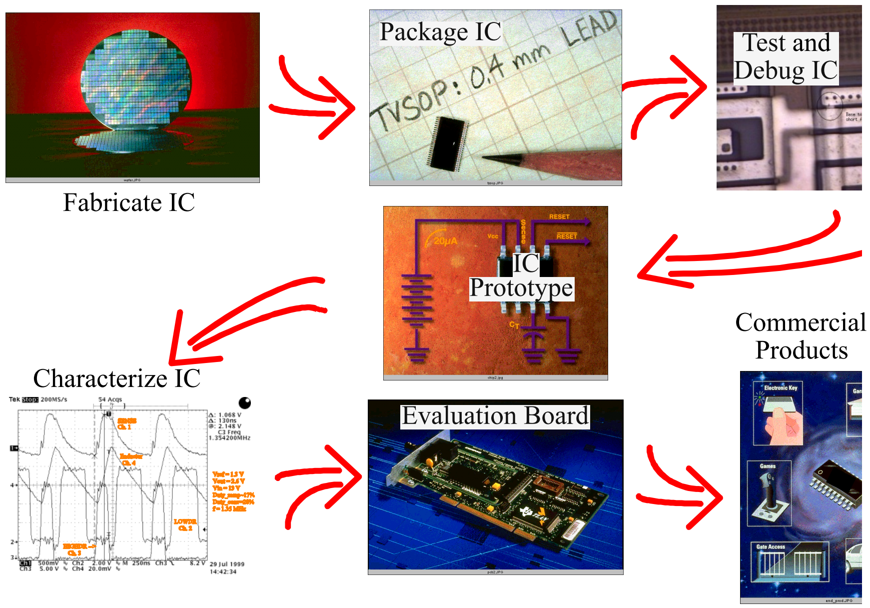
What is the design process really like?



Why do I have a passion for analog IC design?

It is *challenging*:

Analog circuits are sensitive

to noise, supplies, loads, temperature, process, and others factors.

It is a *creative* process:

There is no unique logical method to design a circuit.

It is like painting a portrait and writing a poem,

except we use semiconductors to create our art.

It must be *insightful* and *intuitive*:

Cannot design complex analog systems from equations or truth tables.

Must understand how to condition and process real-life continuous-time

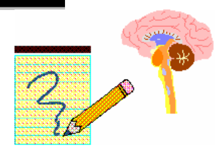
signals under extreme conditions (e.g., temperatures, voltages, noise, etc.).

Why do I have a passion for analog IC design?

It is *state-of-the-art* work:

Use and master latest technologies.

It is a *difficult*, yet *simple* process:



Basic requirements are

pencil, paper, and a skilled engineer.

Best designs: Often conceived and drawn on a small piece of paper.

Computer: As good as the user → Like with software, "*Garbage in*, *garbage out*."

∴ Good to verify, tweak, and document, but *not* to design.

Ultimately, the circuit and the end product are rewarding, but not as much as

the design process, the sense of accomplishment, and the eventual impact.