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 delivery. Consequently, all electronic systems must necessarily 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 (e.g., pacemakers, nanotechnology probes, and so on) and commercial products (e.g., laptops, cellular phones, microsensors, and more) to military (e.g., unmanned aerial vehicles, light-weight electronic equipment, etc.) and space exploration applications (e.g., remote metering, robots, and so forth). It is therefore impossible to fathom engineering real-life solutions without the help and support of high-performance analog electronics.

Analog Integrated Circuit Design – Why?
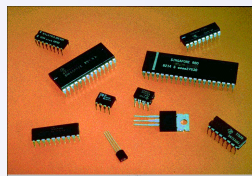
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Outline

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 like analog IC design?

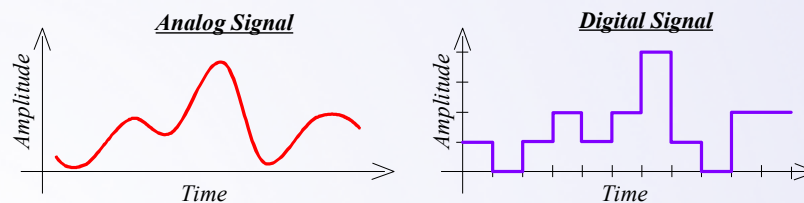## What is the *difference between analog and digital signals?*

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.

Analog Signal

Digital Signal

Infinite versus finite number of states → Analog = digital + every point in between

Analog Integrated Circuit Design: Why?

Why analog?

Fact: Physical signals are continuous in time and amplitude ➔ *Analog*
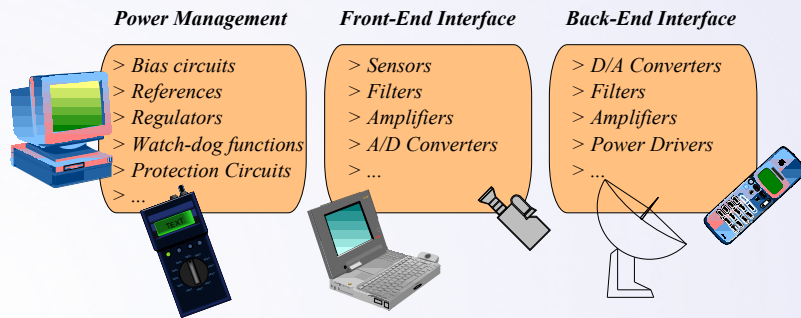
E.g.: Seismic, Audio, Video, Biological, and so on.
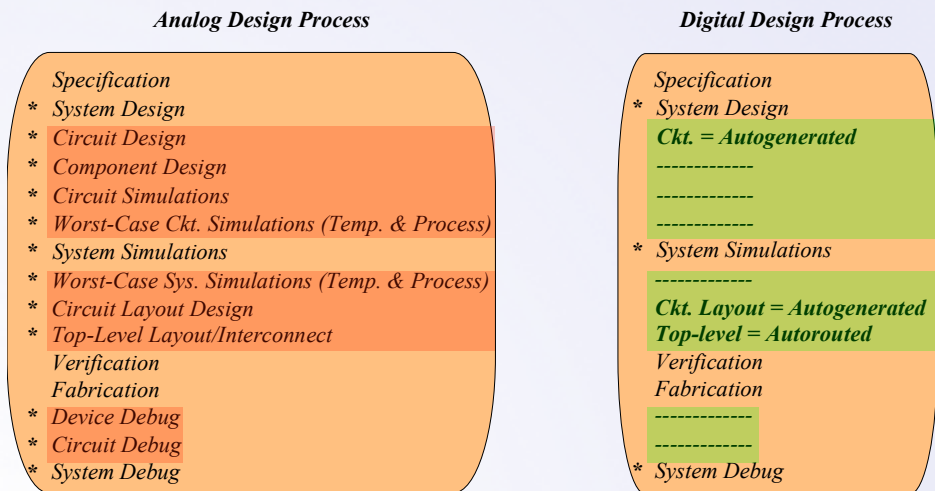
But: Digital signals are easier to process and more robust

I.e.: More room for error ➔ *Higher noise immunity*

So: Process as much as possible in digital domain,

But since the world is analog, *analog processing is still required*.

Power Management

> *Bias circuits*
> *References*
> *Regulators*
> *Watch-dog functions*
> *Protection Circuits*
> *...*

Front-End Interface

> *Sensors*
> *Filters*
> *Amplifiers*
> *A/D Converters*
> *...*

Back-End Interface

> *D/A Converters*
> *Filters*
> *Amplifiers*
> *Power Drivers*
> *...*

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*
> -------------
> -------------
> -------------
* *System Simulations*
> -------------
> *Ckt. Layout = Autogenerated*
> *Top-level = Autorouted*
> *Verification*
> *Fabrication*
> -------------
> -------------
* *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 to 90% Digital and 10 to 50% Analog

    Die is mostly digital → Process technologies are optimized for digital circuits.

Design-time Syndrome:

    In 10%–90% analog–digital die, 10% analog demands 90% of *total* design time.

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

Analog design cannot be automated, so there are no standard cell libraries.

    E.g.: Operational Amplifier → Continually redesigned because every

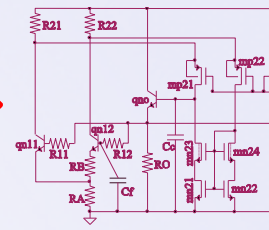   application and process has specific requirements/constraints.

        Analog design is difficult, challenging, and always new,

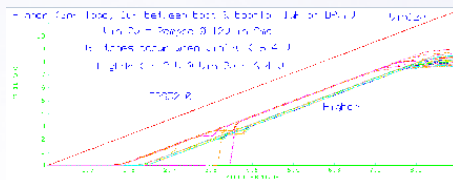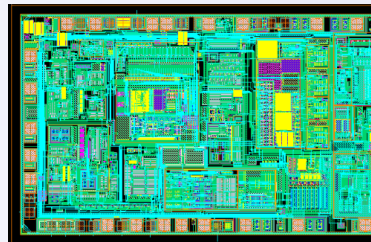   so analog IC designers are always in high demand.

What is the design process really like?
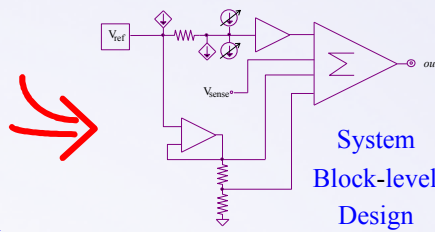
Transistor-level Circuit Design

V_{ref}

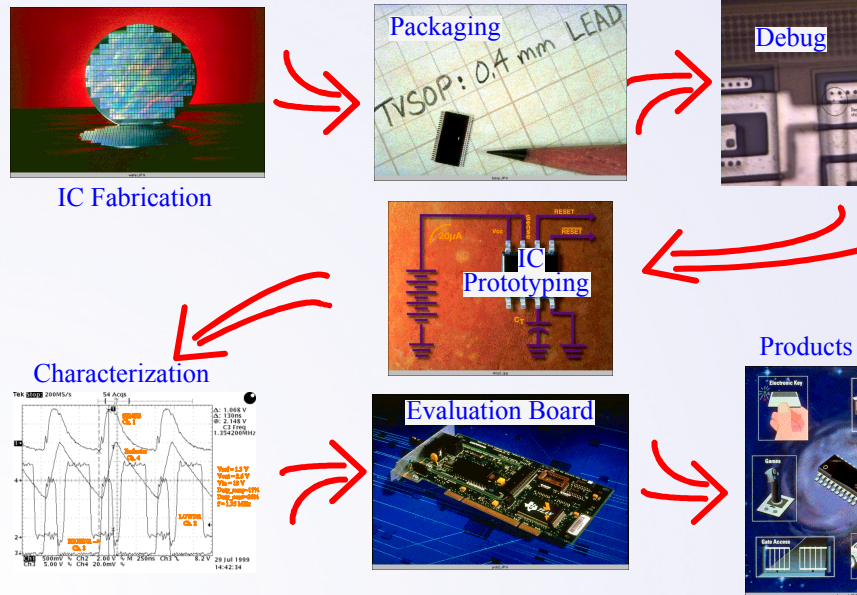V_{sense}

out

Brainstorm

System Block-level Design

Physical (Layout) Design

Design Verification → Simulations

Analog Integrated Circuit Design: Why?

What is the design process really like?

IC Fabrication → Packaging → Debug → IC Prototyping → Characterization → Evaluation Board → Products

Why do I like analog IC design?
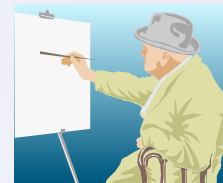
It is challenging:

> Analog circuits are sensitive
>
>> to noise, supplies, loads, temperature, process, and others factors.

It is a creative process:

> There is no clear logical method to design a circuit.
>
> Like painting a picture or writing a poem,
>
>> except we use semiconductors to create our art.

It must be insightful and intuitive:

> *Cannot* design 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.)

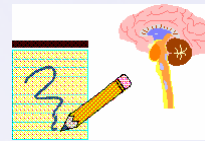*Why do I like analog IC design?*

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 an analog IC design engineer.

Best designs: Often conceived on a scrap piece of paper, and sometimes in dreams.

Computer: "Garbage in, garbage out"

→ Only good to verify, tweak, and document, but not to design.

Ultimately, it is not the circuit or end product that is exciting;

it is the process of designing it and the sense of accomplishment.