



ON Semiconductor®

**Mixed Signal Design
Junior Seminar**

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Who is ON Semiconductor?



ON Semiconductor®

- Spin off of Motorola in 1999 (Standard IC products & Discrete power components)  **MOTOROLA**
- Growth – Intrinsic & Acquisition
 - Cherry, Catalyst, PulseCore, CMD, Sound Design  **Cherry Semiconductor**
 - AMI Semiconductor  **AMI SEMICONDUCTOR**
 - SANYO Semiconductor  **SANYO**
 - Cypress Image Sensor, Trusense, Aptina
- 21,000 employees, \$2.8B Revenue, #4 in class
- ON Semiconductor Today – Discrete components & Custom IC's



“Driving Innovation in Energy Efficient Electronics”



Utah Design Center (UTDC) American Fork, UT

- Locations
 - Head Quarters – Phoenix, AZ
 - Design Centers – **American Fork, UT**; Pocatello, ID; Philadelphia, PA; Phoenix, AZ; Dallas, TX; Bangalore, India; Belgium; Czech Republic; More...
- UTDC comes through AMIS – Mixed Signal Design expertise
- UTDC Charter
 - Design World Class Mixed Signal ASICs
 - Recruit Engineering Talent out of U of U and BYU.
- Ongoing Internship Program
 - Seniors & Graduate Students
 - Fall, Winter, Spring & Summer semesters
- Opportunities for Employment...if interested in MS Design



Mixed-Signal Design

- What kind of design do you like to do?
- Is Digital Logic design your favorite?
- Is Embedded Software design your favorite?
- Is Analog Transistor level design your favorite?
- Or do you like them all!



What is Mixed-Signal Design?

- Mixed Signal Designs include both Analog and Digital circuits on the same Integrated Circuit.
- What are Analog Circuits - I/Os, Amplifiers, Oscillators, Comparators, Regulators, References, Temperature Sensors, Data Converters, Level shifters, etc.
- What are Digital Circuits – Logic gates, State Machines, Control, Microprocessors with Firmware, Memories, Communication, Programmability, Analog Trim, FPGA's etc.
- Are all Digital IC's Mixed Signal?
- Are all Analog IC's Mixed Signal?



Why Mixed-Signal Design?

- The Real World is Analog – Colors, Sounds 🔔, Temperatures **, Textures, Motion, etc.
- Transducers turn the Analog world into Voltage and Current signals.
- Analog Circuits are the “senses” of the Integrated Circuit – they condition the signal and prepare it for interpretation and manipulation.
- Digital Circuits and Software are the “brains” of the Integrated Circuit – they efficiently process the information.
- Analog Circuits create the “action” as they send the interpretation or modified signal back into the real world.
- Analog to Digital (ADC) Converters and Digital to Analog Converters (DAC) link the senses to the brain and the brain to the action.



Some Mixed Signal Applications



Cell Phones



HD TV's



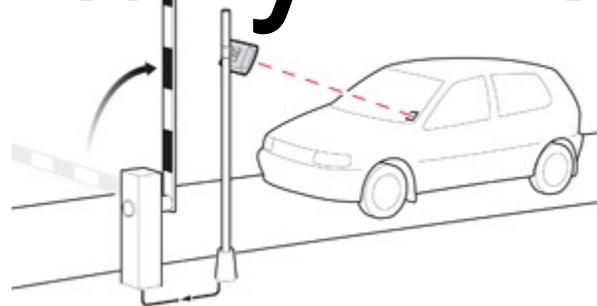
Circuit Breakers



Medical Imaging



Magnetic Card Readers



RFID and Automotive



Appliances

Many More.



Why Mixed Signal Integrated Circuits?

- As applications become smaller and more complex, there is pressure to save board space and power

- Cell phones
- Tablet computers
- RF ID sensors
- MP3 players
- Laptops



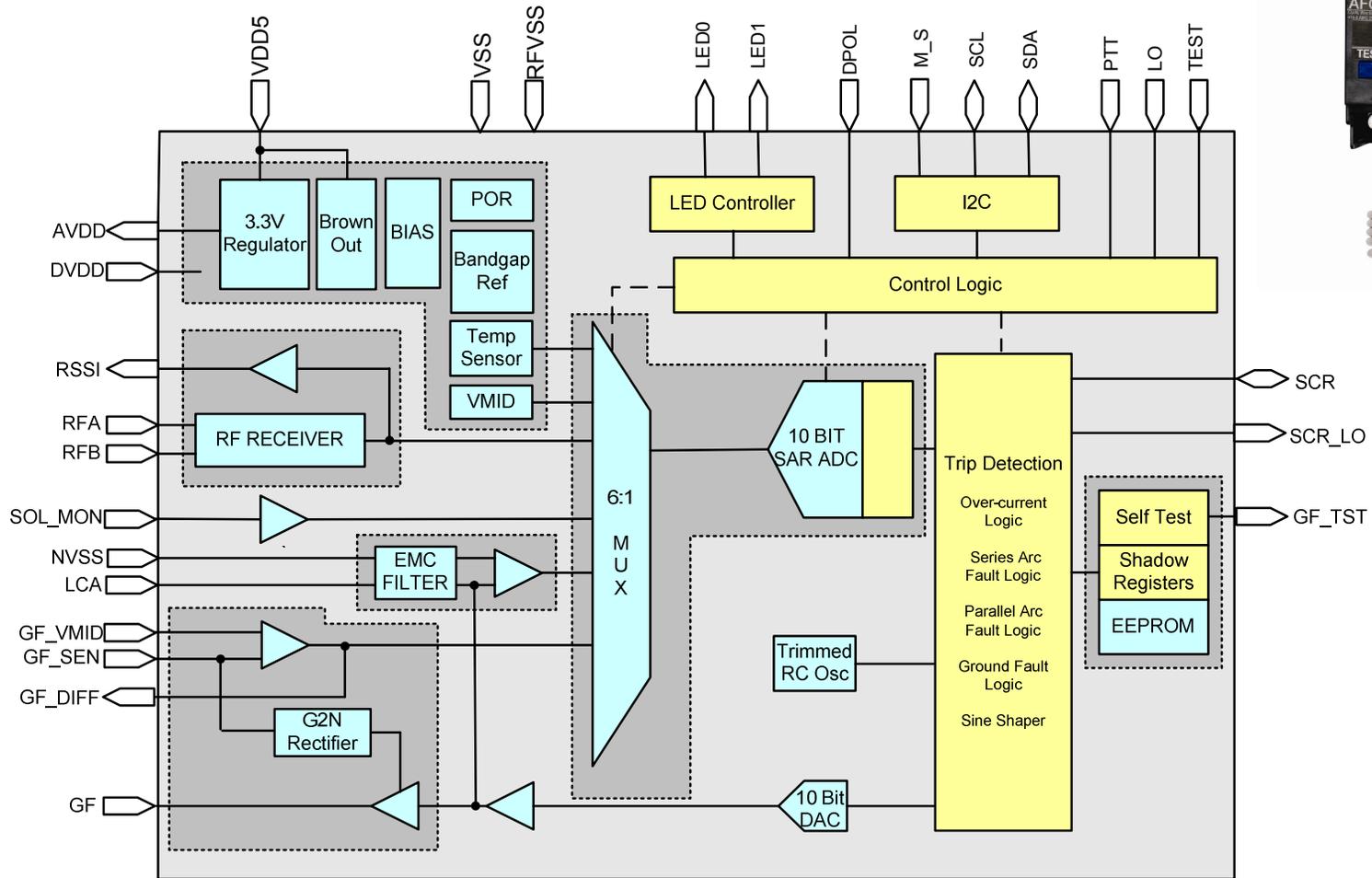
- Improvements in digital technologies have allowed processing power to be applied to “old school” analog applications

- Automotive
- Industrial control
- Power management
- Audio
- Displays (Flatscreen monitors, touchscreens, HDTV, 3-D TV)



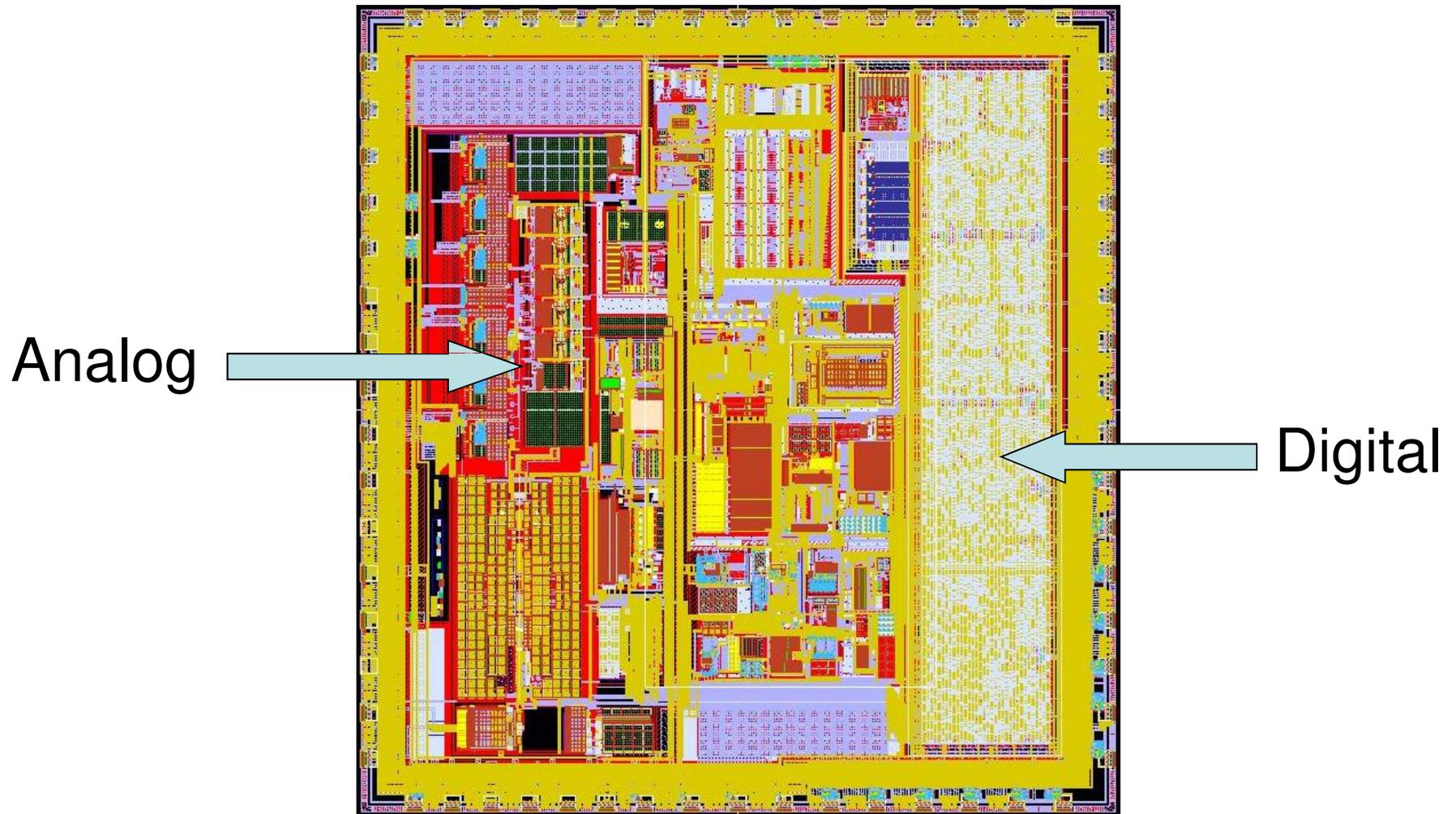
Examples of Mixed-Signal Designs

AFCI/GFCI Circuit Breaker IC



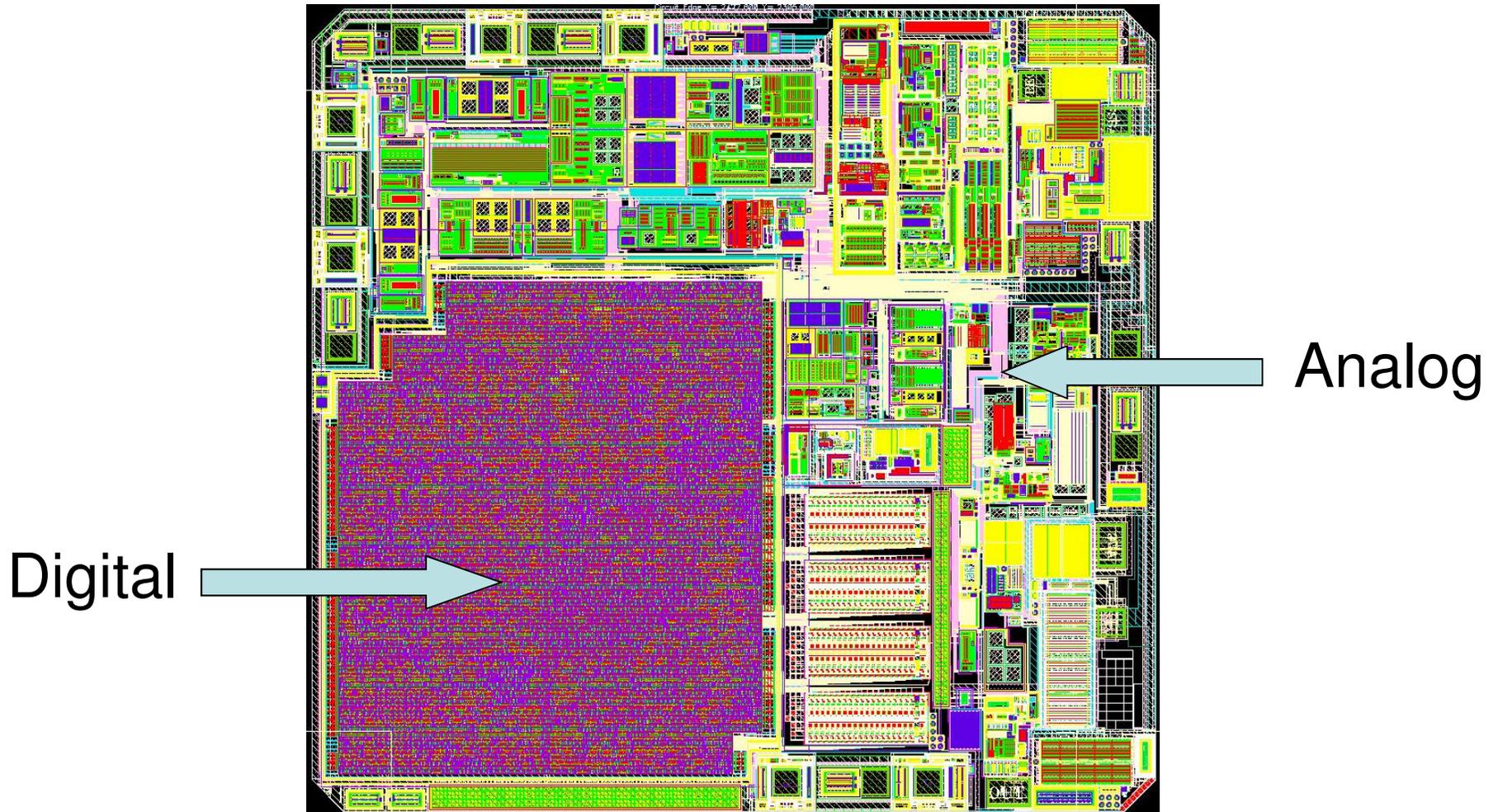
Examples of Mixed-Signal Designs

AFCI/GFCI Circuit Breaker IC



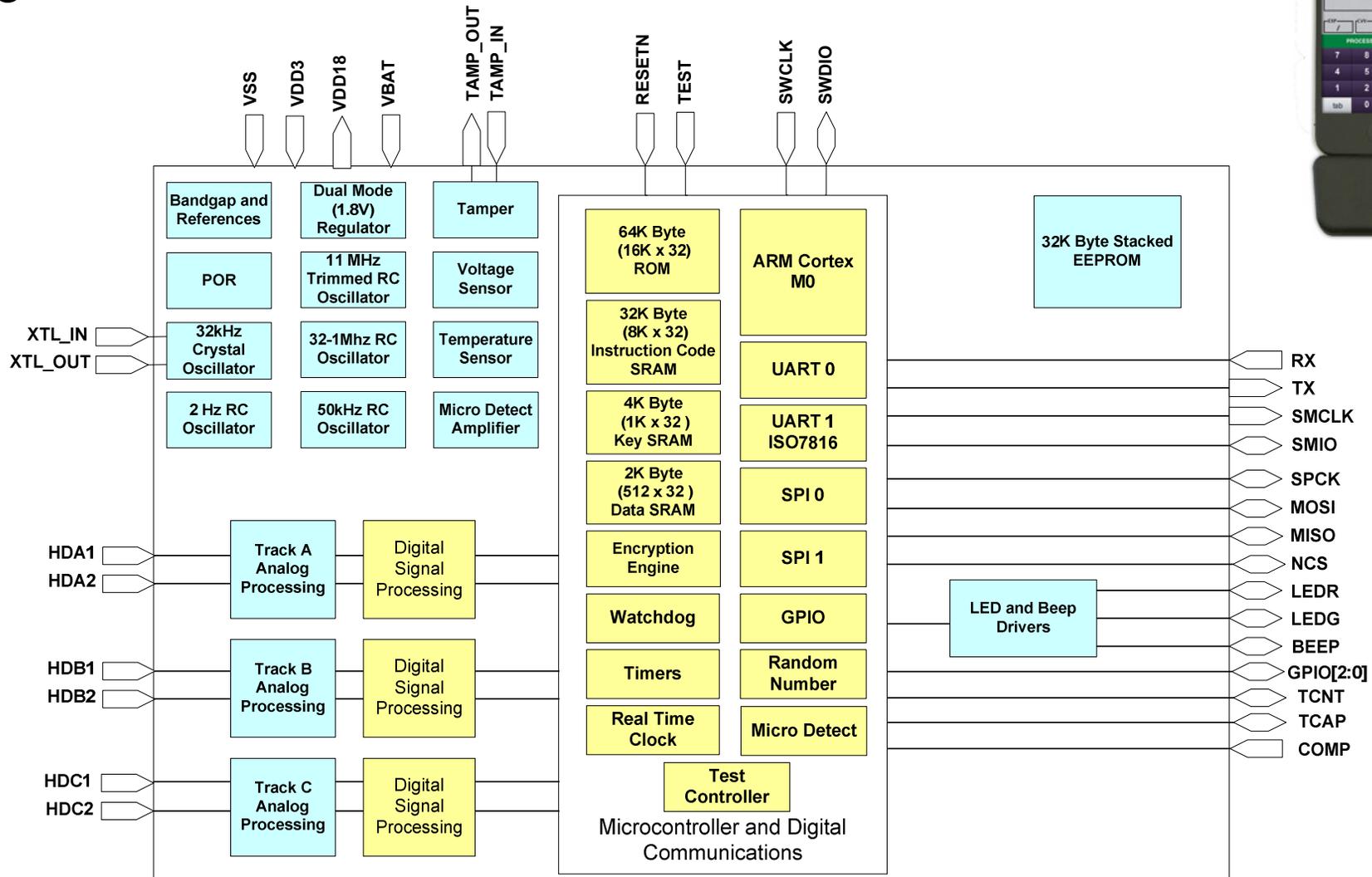
Examples of Mixed-Signal Designs

Automotive Angle Position Sensor IC



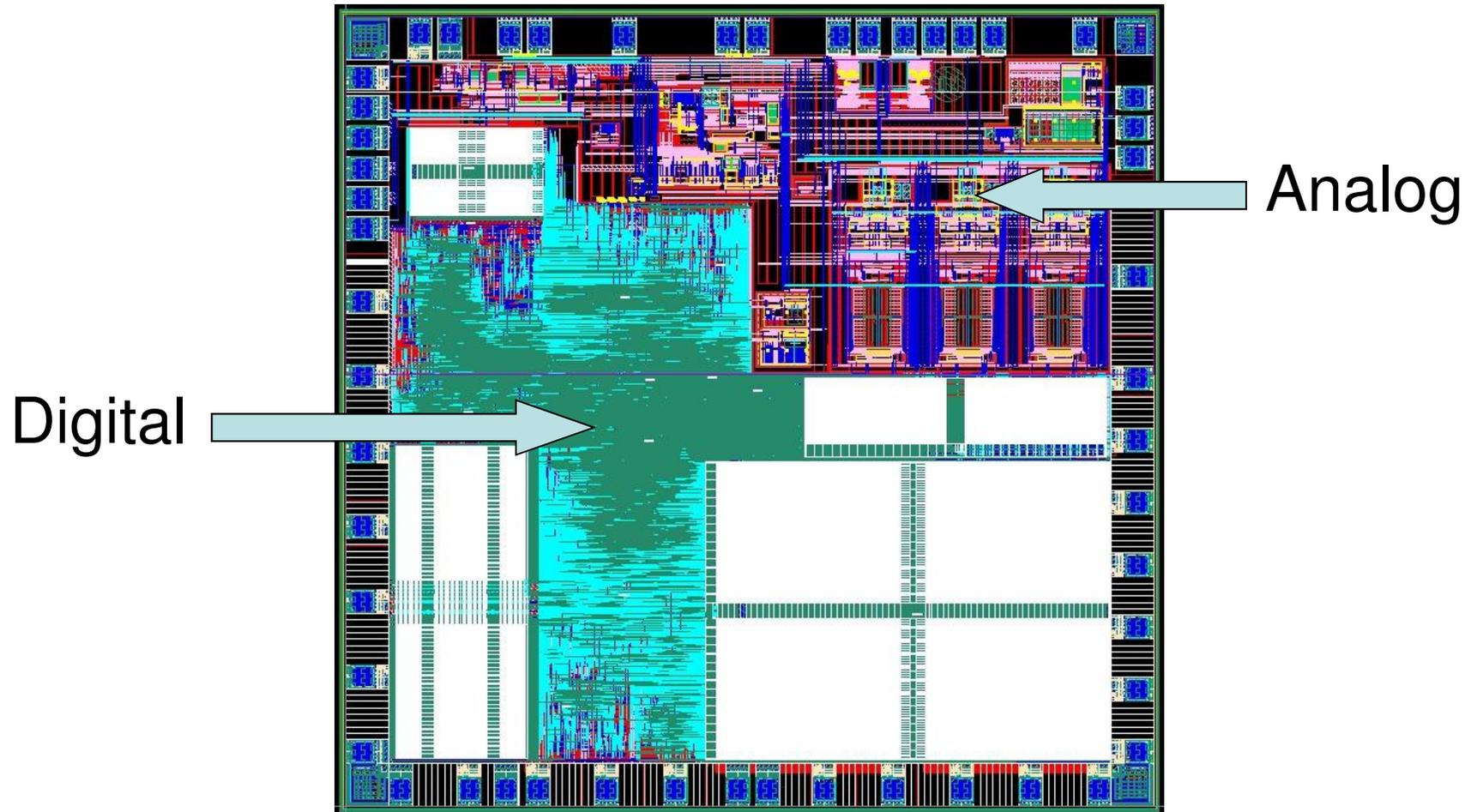
Examples of Mixed-Signal Designs

Magnetic Card Reader IC



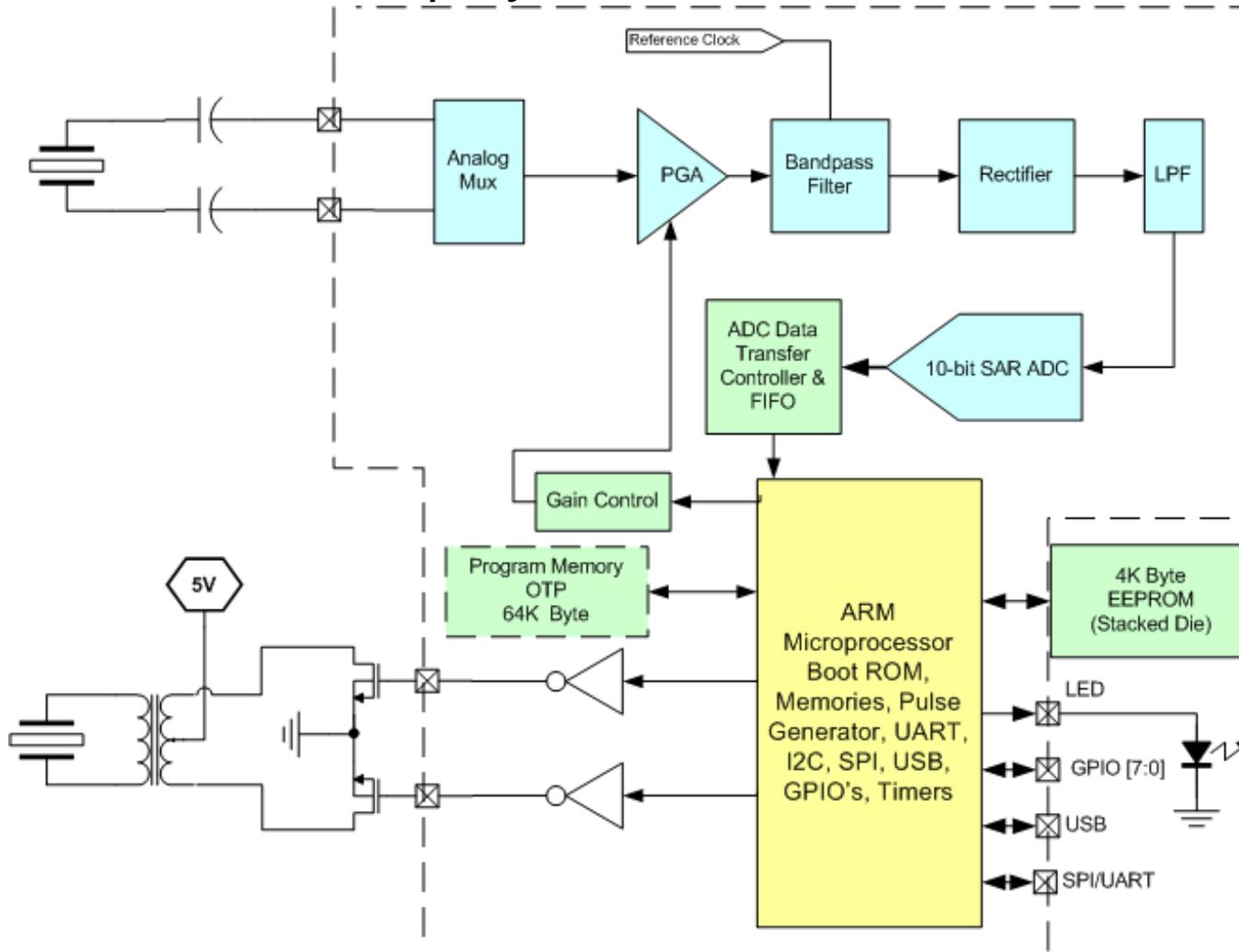
Examples of Mixed-Signal Designs

Magnetic Card Reader IC



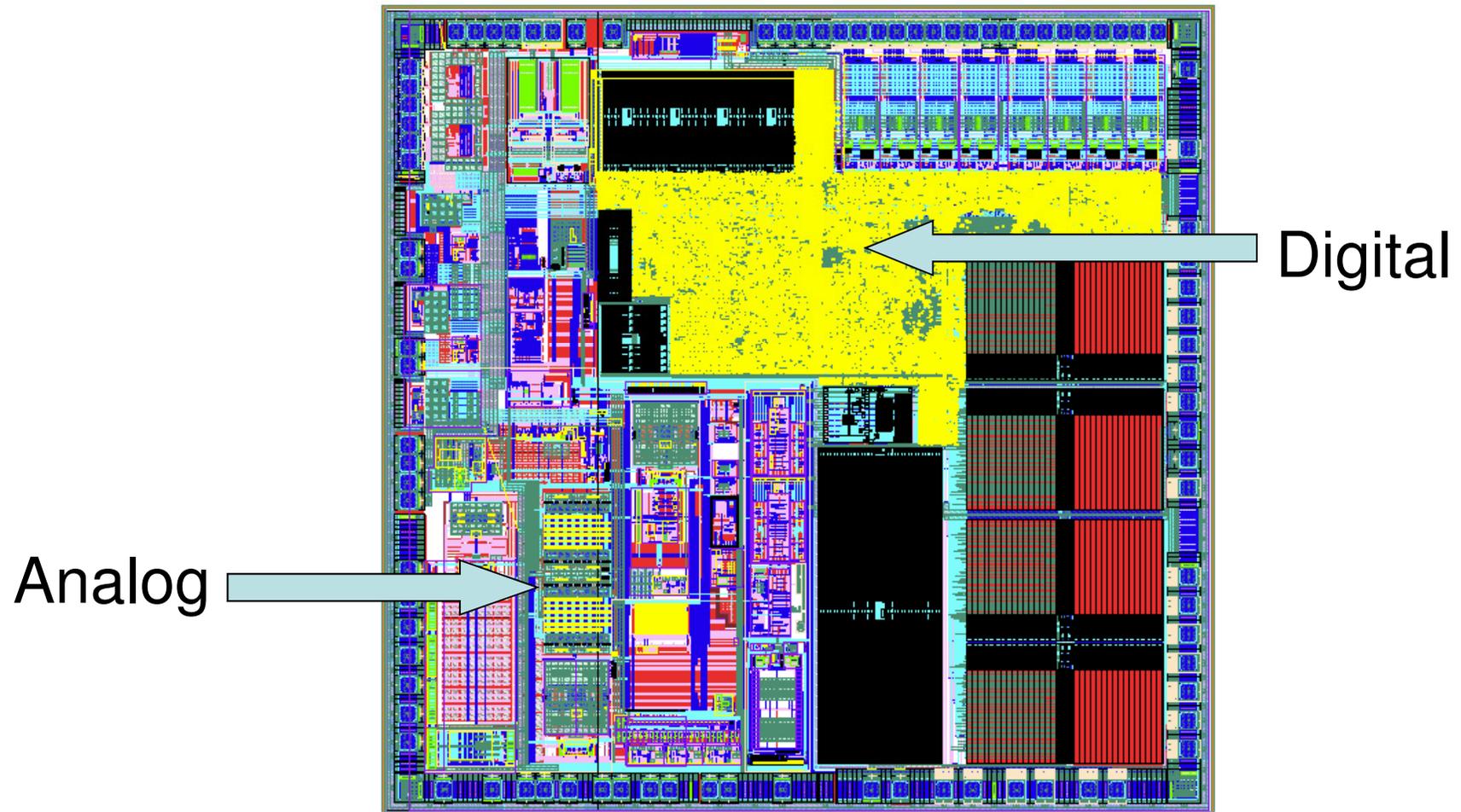
Examples of Mixed-Signal Designs

Touch Screen Display



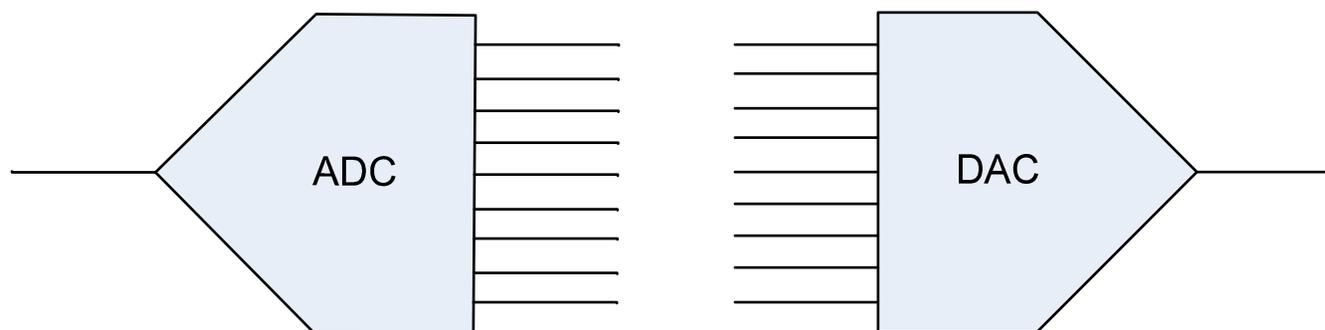
Examples of Mixed-Signal Designs

Touch Screen Display



Challenge: How to choose the right Data Converter

- How do you know which ADC or DAC you should use?



- Questions to ask:
 - How many bits do I need?
 - What is the required conversion rate?
 - How much area on the IC do I have?
 - Which Architecture will best support this application?

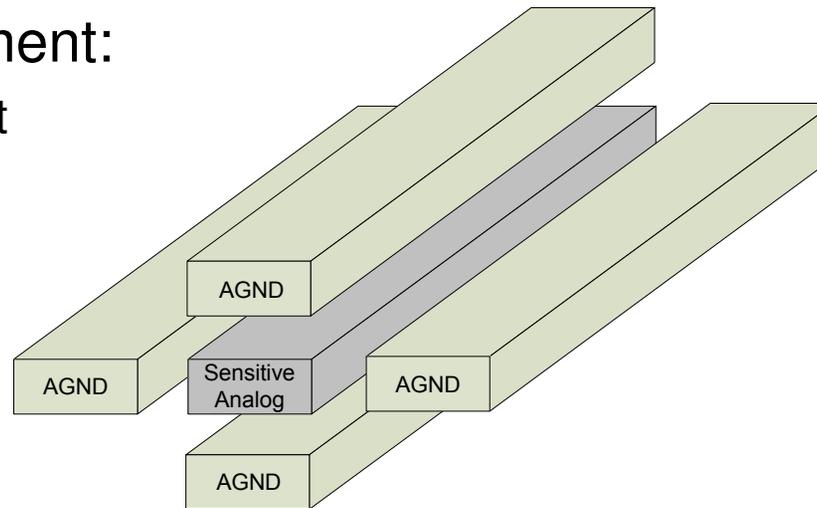
Challenge: Mixed-Signal Verification

- Verify Analog, Digital, and Firmware Independently (Good).
- Capture Analog to Digital & Digital to Analog Interfaces and play back in the independent simulations (Better)
- Mixed-mode Simulations with Analog, Digital, and Firmware in one simulation environment. (Best)
 - Combines both a transistor level and RTL level simulator: ex: Cadence Spectre/Verilog or AMS simulators.



Challenge: Mixed-Signal Noise Management

- Many Possible Electrical Noise Sources in Mixed Signal Design.
- Which is most sensitive to noise – Analog or Digital?
- Noise Sources:
 - Power supply noise coupling
 - Substrate noise coupling
 - Line to line noise coupling
- Noise management:
 - Physical Layout
 - Power modes



Noise Management Example: Silicon Coaxial Shielding

Challenge: Mixed-Signal IC Testing

- Every part of the IC design must be tested.
- Design for Test (DFT) planning needs to include test modes to be able to access direct inputs and outputs of Analog circuits.
- DFT planning needs to include a digital test mode using serial scan-chains and ATPG (Automatic Test Pattern Generation).



Why Become a Mixed Signal IC Designer?

- Be a true designer
- Find new ways to solve the worlds problems
- Large variety of applications, industries, and technologies
- High demand skill set (portable to other industries)
- Work with diverse teams of engineers, customers, and professionals
- Opportunities for patents and publications
- Fun, challenging, diverse work experience
- \$\$\$\$



How to become a Mixed Signal Designer

- Complete a variety of courses in both Analog and Digital Integrated Circuit design techniques as well as Computer Architecture, Embedded Software, IC Testing and Verification, Digital Signal Processing (DSP), Communications, RF, etc.
- Mixed Signal Designers generally have some areas of expertise on different facets of Analog, Digital, or Software design with a good understanding of the other areas.



How to become a Mixed Signal Designer

- Core Courses
 - 2260 Fund Electric Circuits
 - 2280 Fund Eng Electronics
 - 1410/2000 Computer Programming
 - 3700 Digital Systems Design
 - 3110 Engineering Electronics II
 - 3510 Introduction to Feedback Systems
 - 5710 Digital VLSI Design
 - 5720 Analog Integrated Circuit Design
- Mixed-Signal Circuit Design Senior Project
- Other Helpful Courses
 - 3710 Computer Design Laboratory
 - 3810 Computer Organization
 - 5530, 5580 Digital Signal Processing
 - 5201, 5202 Semiconductor Physics
 - 5740 Computer Aided Design of Digital Circuits
 - 5745 Testing and Verification of Digital Circuits
 - 5780 Embedded System Design
 - 5830 VLSI Architecture
 - 6770 Advanced Digital VLSI System Design
 - 6721 Analog Integrated Circuits Lab



Ethics In Engineering

- What does Ethics have to do with Engineering?
- Engineering is about creating using ideas and information
- Ideas and information are valuable assets called Intellectual Property (IP)
 - Engineers need to protect their company/customers/partners IP
 - Engineers must avoid “stealing” IP that isn’t theirs or their customers
 - Re-use of your own IP is a great idea, however it is unethical to use IP that is not yours (from the internet, conference paper, peers, previous employer).



Ethics In Engineering

- Engineers manage technical activities
 - Sometimes tough decisions need to be made regarding doing it right or doing it on-time. The goal is to do both.
 - Products can always be better – engineers decide when is it good enough.
 - Cutting corners always has a cost
 - Supporting data must be sound and have integrity.
- Sometimes the ethical decision is not clear, but engineers have the tools needed to make the right and ethical choice.



Mixed Signal Design Questions?

- Questions?



References

- ON Semiconductor Utah Design Center, Engineers & Designs
- The Fundamentals of Mixed Signal Testing, Nov 2007 (Soft Test, Inc.)
- All About Circuits (www.allaboutcircuits.com), 1999-2000
- CMOS Circuit Design, Layout, and Simulation, 1998 (IEEE PRESS)

