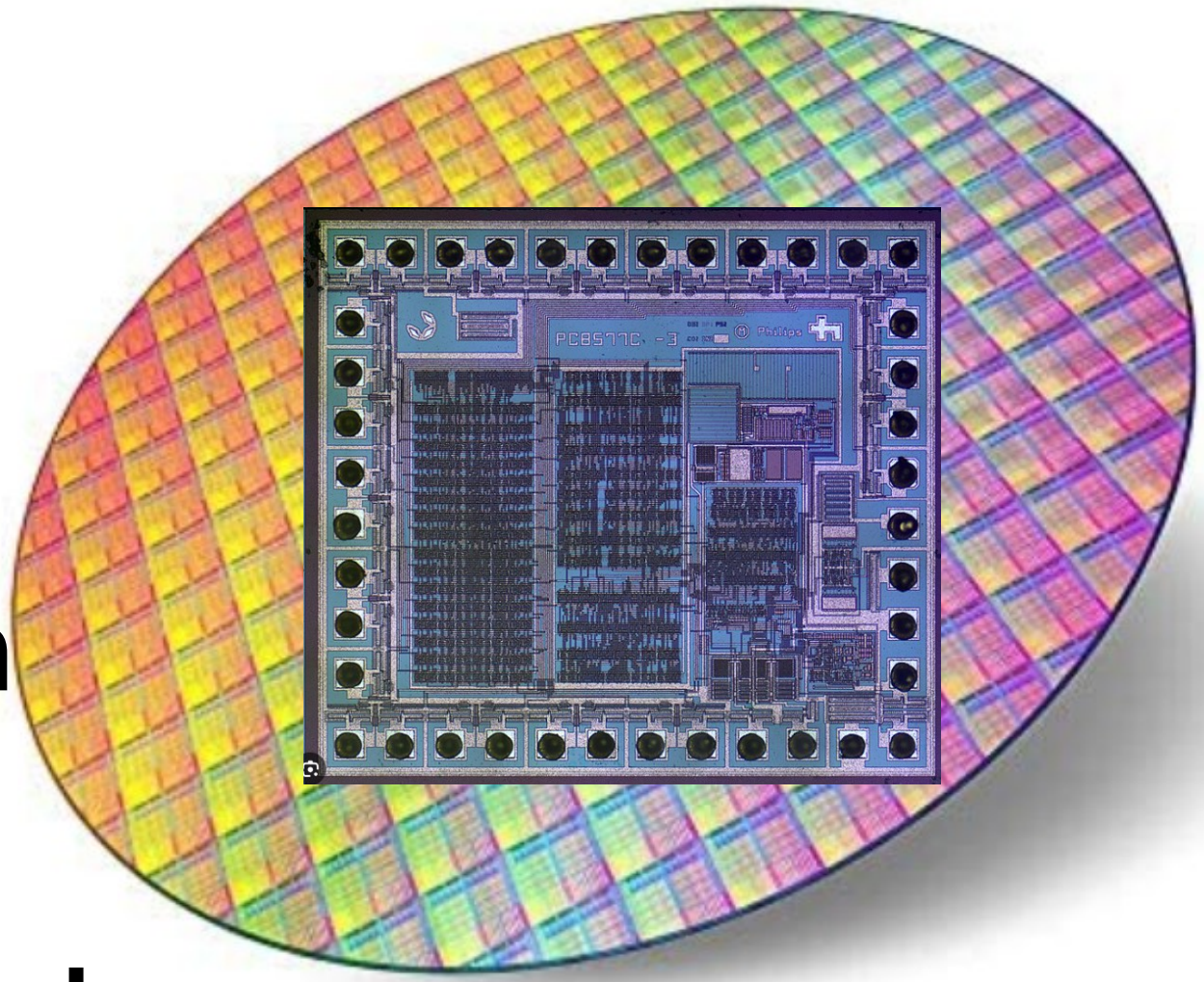
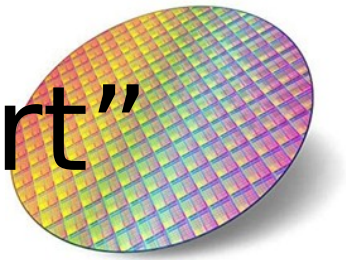
DTU Chip Day 2026

Analog IC design education

Professor Per Lynggaard
DTU Electro



Analog IC-design – the ”black art”



- **Jim Williams (Linear Technology Legend):**

  "I didn't believe anybody could, or should, try to explain how to do analog design... I think [the human factor] is responsible for some of the **mystique associated with analog design**."
  Source: "The Art and Science of Analog Circuit Design"

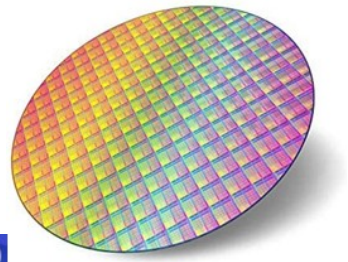
- **Bob Pease (National Semiconductor Guru):**

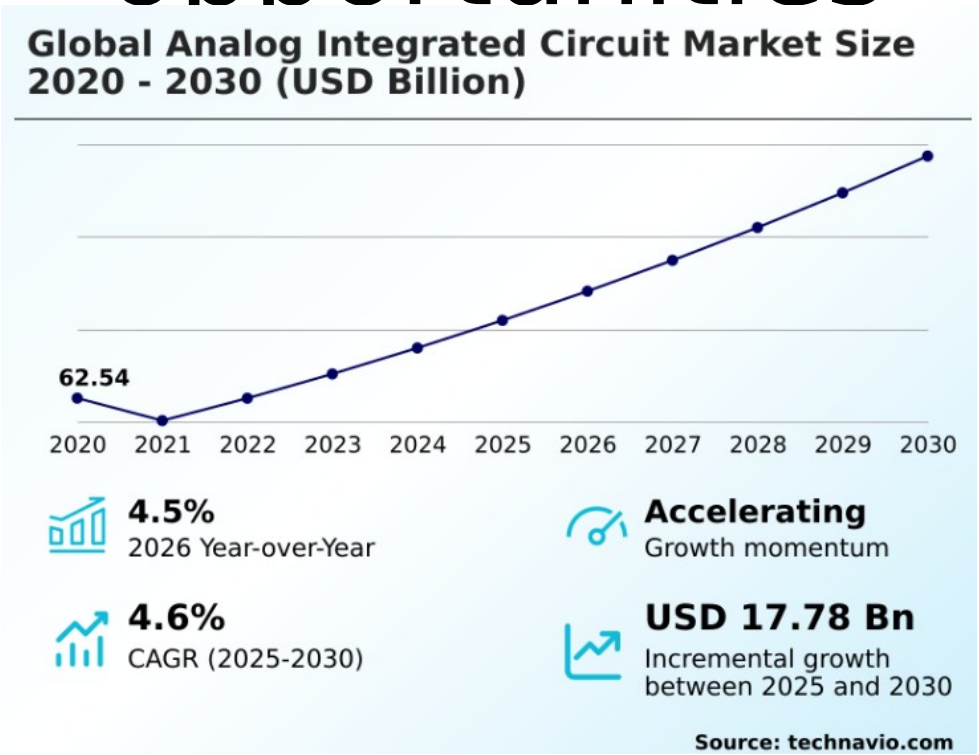
  "Analog is a mix of art, science, modeling, bench testing, and compromise... It is **still an art to some extent.**"
  Source: Electronic Design, "Pease Porridge" Column

- **EE Times (Industry Journal):**

  "I have seen industry pay top dollar for these highly specialized skills... this is knowledge that analog engineers acquired the hard way, by slogging away in the trenches learning what's **basically a black art.**"
  Source: "Analog Engineers: Too Few or Too Many?"

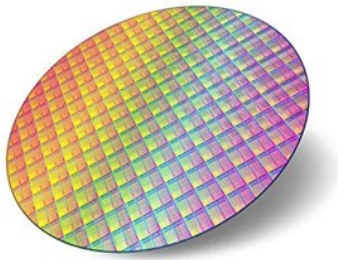
The future of analog IC’s & job opportunities





Region	Target / Need	Source
Global	1,000,000 new workers	Deloitte
Europe	100,000+ new engineers	SEMI / EU Chips Act
USA	67,000 technical worker gap	SIA / Oxford Economics
Asia-Pacific	200,000+ engineer gap	SEMI

EU chip-act



- Chips are strategic assets for key industrial value chains. With the digital transformation, new markets for the chip industry are emerging such as highly automated cars, cloud, Internet of Things, connectivity, space, defence and supercomputers.
- In total, more than €43 billion of policy-driven investment will support the Chips Act until 2030, which will be broadly matched by long-term private investment.

The need for EU action

1 trillion
microchips were manufactured around the world in 2020

10%
EU's share of the global microchips market

Strengthen Europe's research and technology leadership towards smaller and faster chips

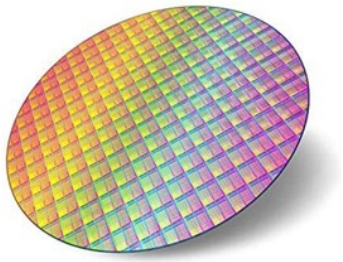
Put in place a framework to increase production capacity to 20% of the global market by 2030

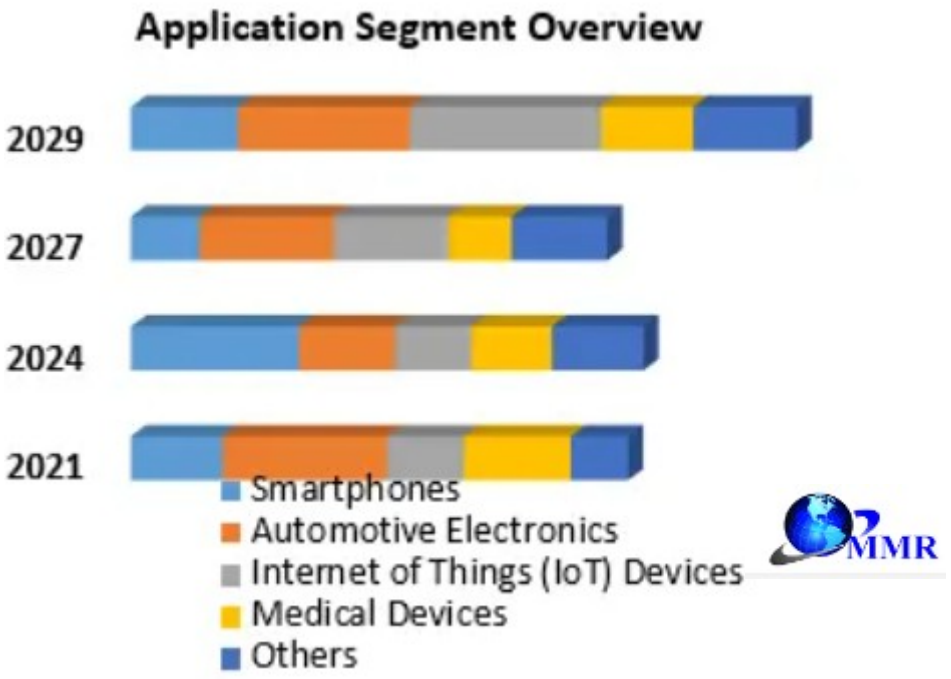
Build and reinforce capacity to innovate in the design, manufacturing and packaging of advanced chips

Develop an in-depth understanding of the global semiconductor supply chains

Address the skills shortage, attract new talent and support the emergence of a skilled workforce

Applications

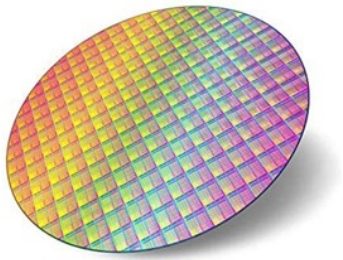




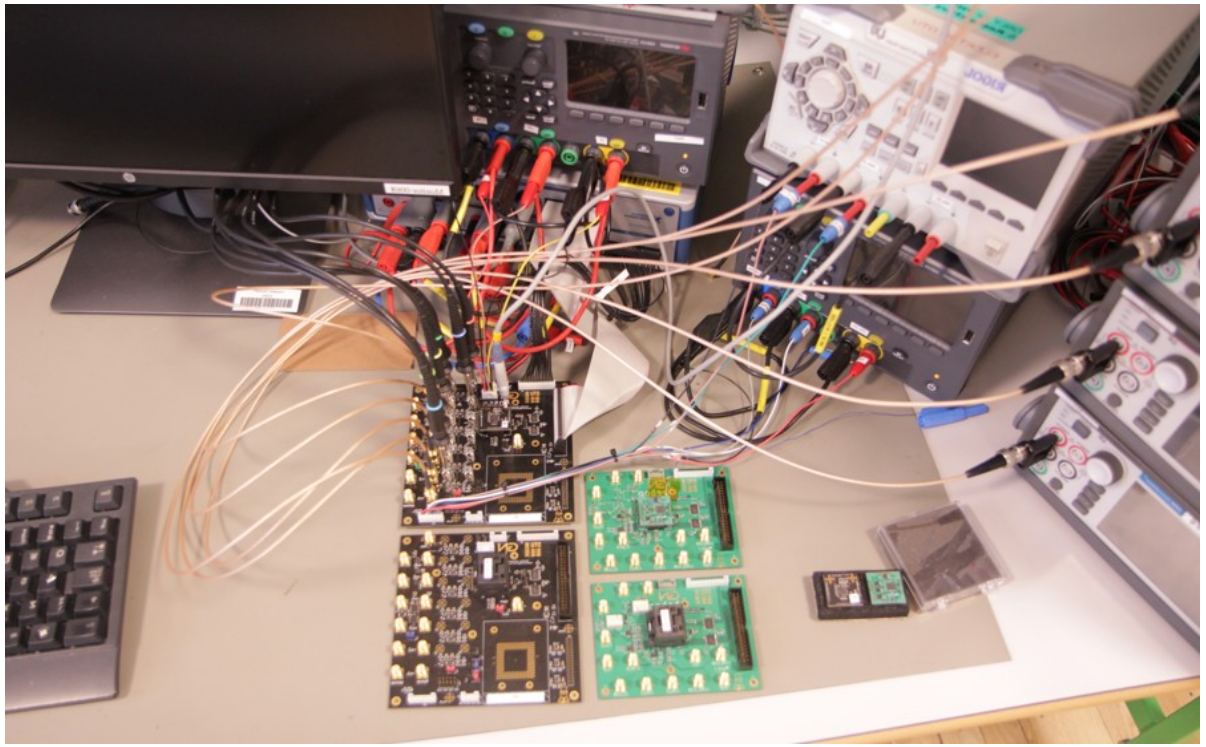
Products and Applications	Top Product Categories for Growth: Sensors / MEMS	Analog	Microprocessors
Internet of things	●	◔	◔
5G	◑	◔	◔
Automotive	●	●	●
Artificial intelligence	◑	◔	●
Consumer electronics	◔	◑	●
Data centers / Storage	◔	◔	●

Source: *KPMG Global semiconductor industry outlook 2021*

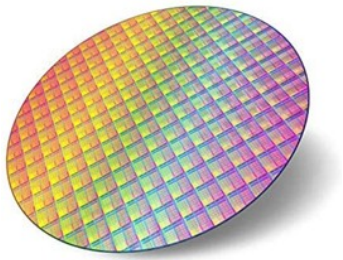
Analog IC design – educations & study lines



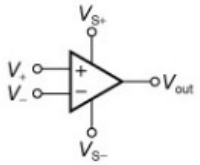
- BSc Electrical Engineering
  - Electronic and electromagnetic systems
- Bachelor in engineering in electrotechnology
  - Electronic and electromagnetic systems
- MSc Electrical Engineering
  - Electronics (new)



34630 - Integrated analog electronics 1 (IC-1)

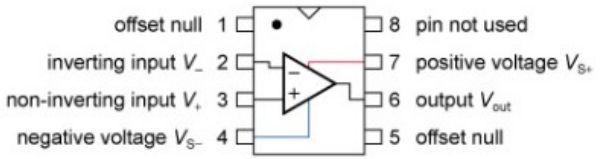


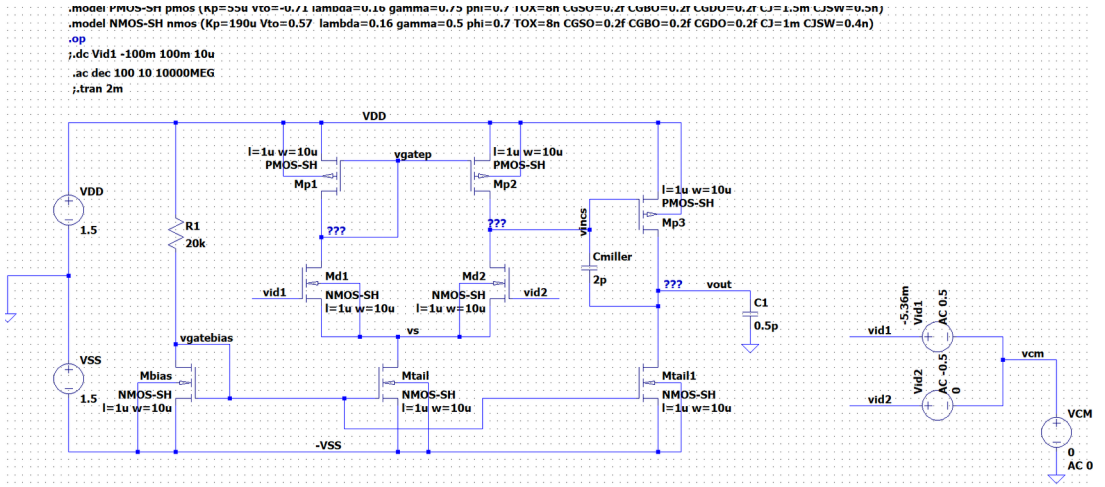
- Models for MOS transistors - used for circuit analysis
- Design a simple two-stage operational amplifier
- Design simple circuits for the generation of bias currents and bias voltage



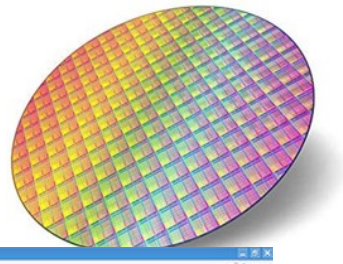
(a)

(b)

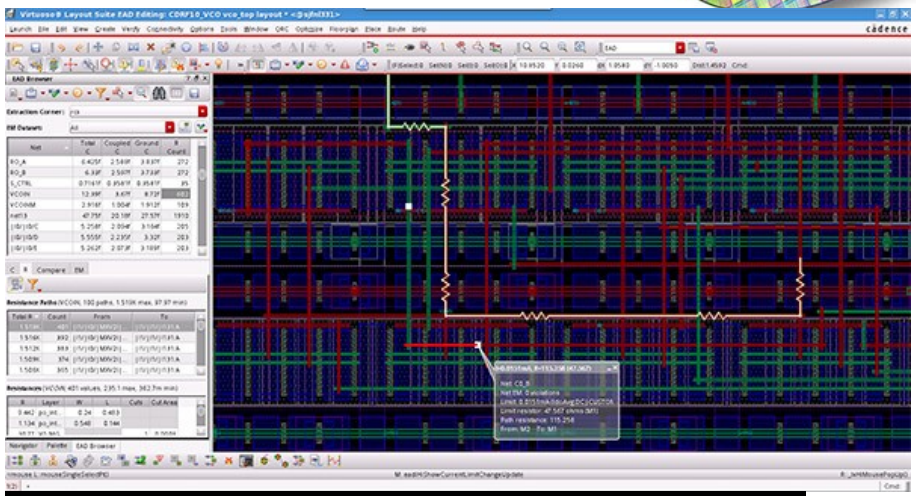


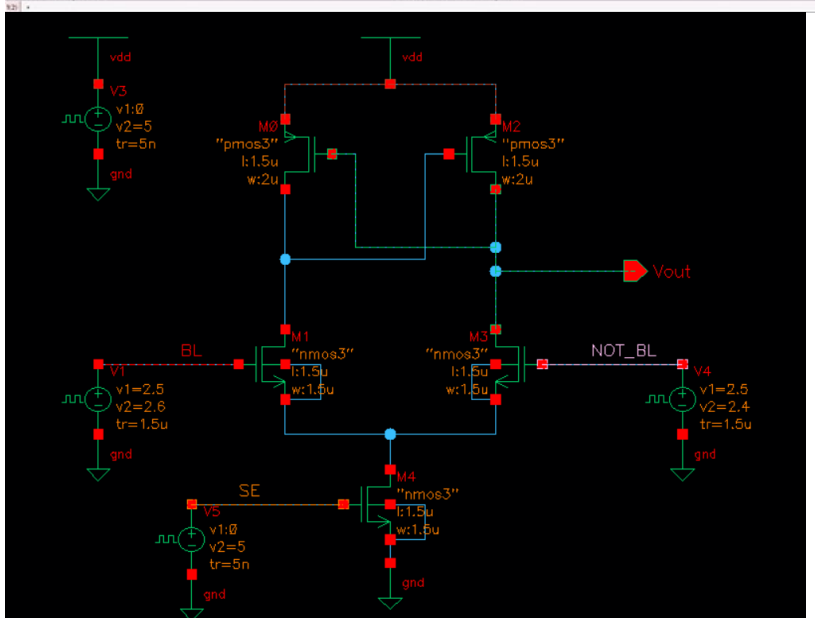


34655 - Integrated analog electronics (IC-2)

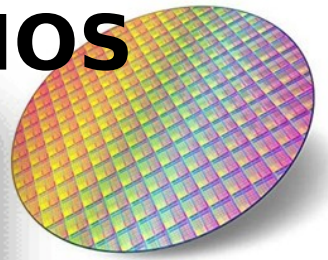


- Enable complete design of integrated analog circuitry from a given specification
- Through schematic design and analysis to a layout ready for manufacturing.

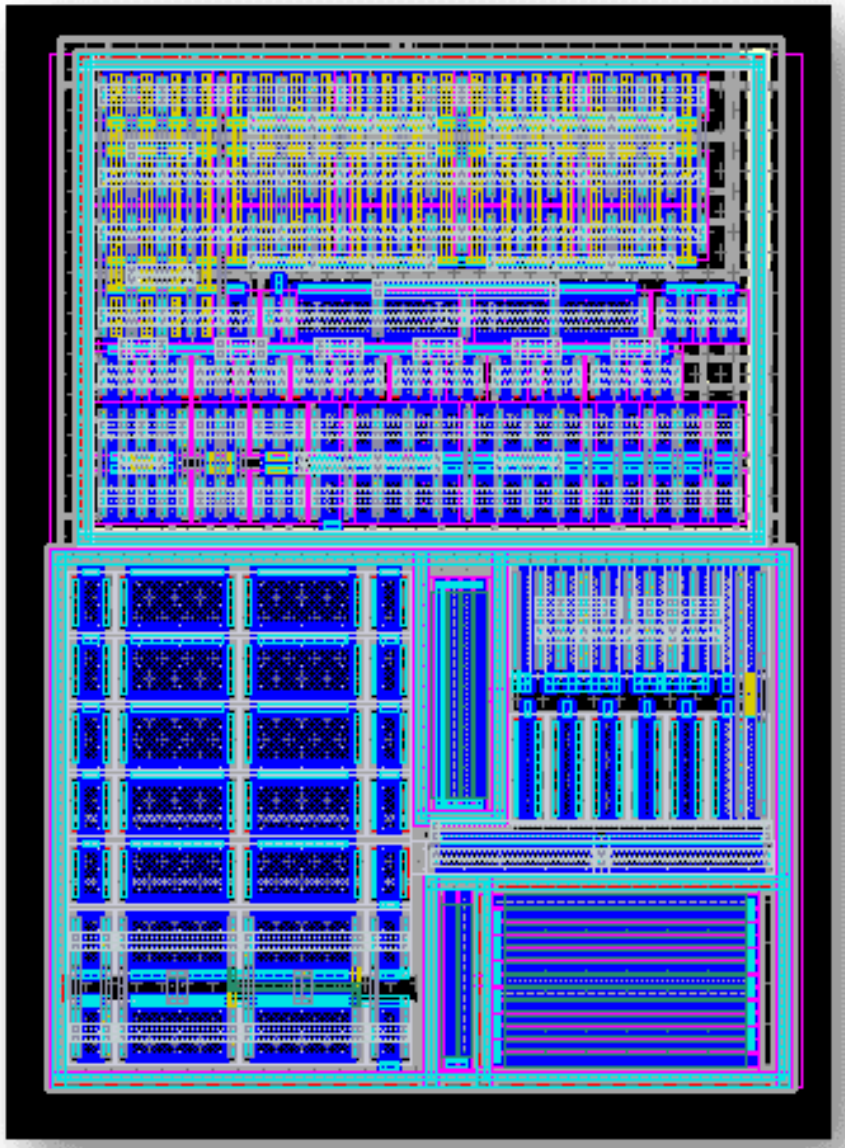




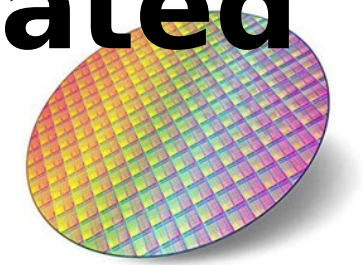
34656- Design and layout of integrated CMOS circuits (IC-3)



- Synthesize an operational amplifier
- Layout of analog circuitry
- Use tools to check the design against temperature, voltage and process variations

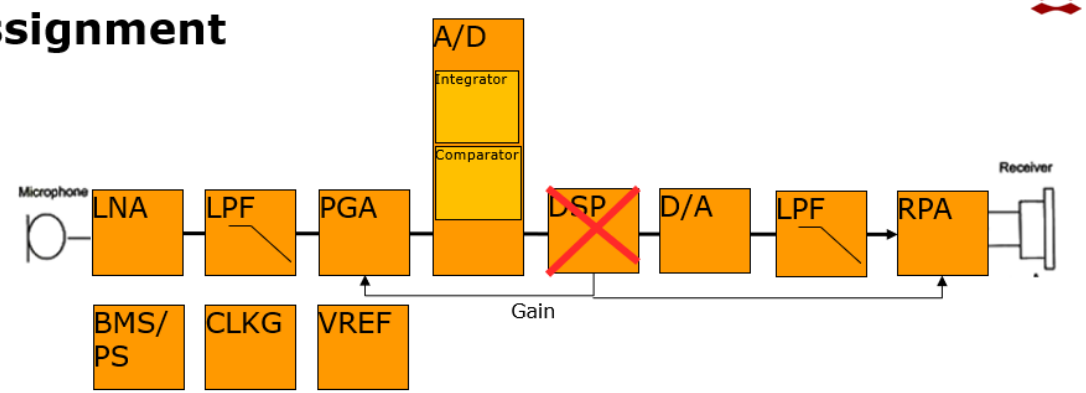


34657 - System level integrated circuit design (IC-4)



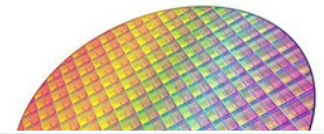
- The full IC design containing several advanced IC blocks
- Based on state-of-the-art literature search
- Design blocks
- Layout the circuit
- Verify its performance and compare it to state of the art.

Assignment



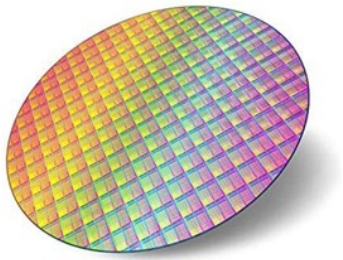
- LNA Low noise amplifier
- LPF Low pass filter
- PGA Programmable gain amplifier
- A/D & D/A analog to dig. / dig. to analog converter
- DSP Digital signal processing
- RPA Receiver power amplifier (with programmable gain)
- BMS / PS Battery management system / power supply
- CLKG Clock generator
- VREF Reference voltage generation

Analog IC design courses



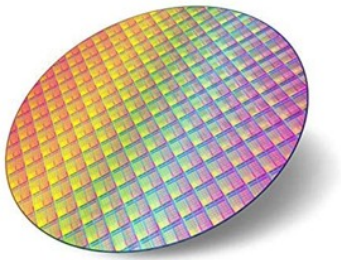
BSc		**ECTS**	**Term**
	34630 - Integrated analog electronics 1	**5**	**Autumn**
	To enable the student to analyze and design analog amplifiers with an emphasis on integrated circuits in CMOS technology.		
MSc			
	34655 - Integrated analog electronics 2	**5**	**Spring**
	To enable the student to conduct a complete design of integrated analog circuitry from a given specification through schematic design and analysis to a layout ready for manufacturing.		
	34656- Design and layout of integrated CMOS circuits	**5**	**June**
	To enable the student to conduct a complete design of integrated analog circuitry from a given specification through schematic design and analysis to a layout ready for manufacturing.		
	34657 - System level integrated circuit design	**10**	**Autumn**
	Enable the student to design and layout an advanced integrated circuit block that is part of a full integrated circuit (IC) and to work in collaboration with other designers to ensure that the full IC operates at a system level.		
PhD			

Research immersion I and II



- **Projects examples:**
- Embedding a small RISC processor in analog IC context for use with Cadence mixed-mode simulation – Implementation
- Automated Integration of OpenROAD Digital Blocks into Cadence with Closed PDK
- Bandgap voltage reference
- Switched-Capacitor Power Converter (use of a design methodology for fully integrated switched-capacitor converters that integrates external capacitors)
- Optimization/Scaling of a Dual-RO-Based IC Temperature Sensor
- Mixed domain noise filter (SoC)

Analog IC design courses – student theses & projects



MSc thesis

2023 Design of high-voltage integrated circuits for driving GaN transistor based switched-capacitor power converter

Temperature sensor cell for multisite on die temperature sensing

2022 Limiting EMI in the class D output stage of a hearing aid

2021 Integrated Class-D Audio Output Stage with Low EMI for Hearing Instrument Applications

Ultra Low Power ADC for Low Bandwidth Signal Acquisition

2020 High Voltage Switched Capacitor Power Converter with AC Input Voltage

Design of a low-power voltage regulator

High-Resolution SAR ADC with Digital Calibration

Integrated voltage reference for space applications

Design of a High Efficiency Highly Integrated DC-DC Power Converter in a 0.13 um Process

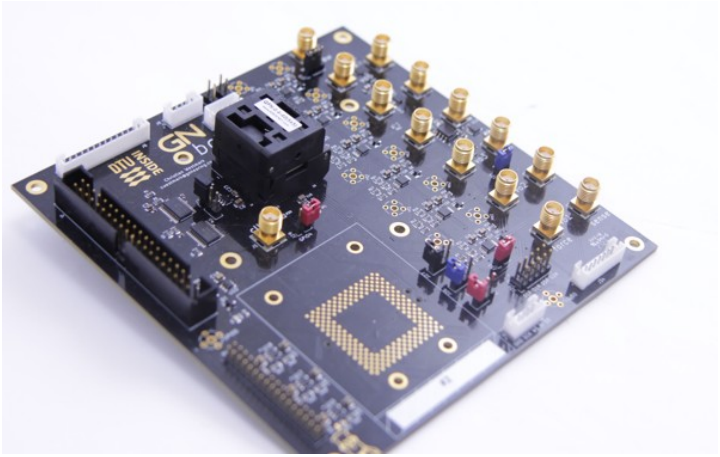
56 Gbaud VCSEL driver

12-bit Incremental Sigma-Delta Analog-to-Digital Converter

Front-end for Voltage Measurement across Capacitor

Design of CMOS Ring Oscillator for 53 Gbaud Serializer/Deserializer Systems

Design of a Sigma-Delta Analog-to-Digital Converter



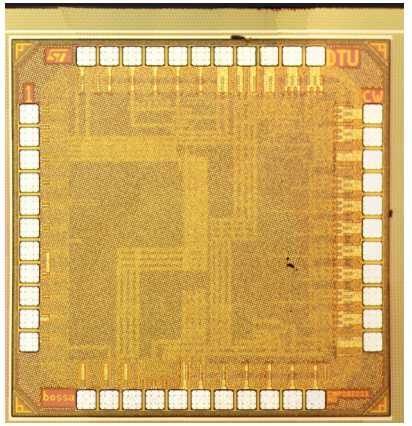
BSc thesis

2023 Investigation of variable delay-line for time-based circuits

Deriving an electrical model of the substrate in a BCD process through layout extraction

2020 Design af High Voltage Level Shifter

Linear Regulator for gate-driver circuits



BEng thesis

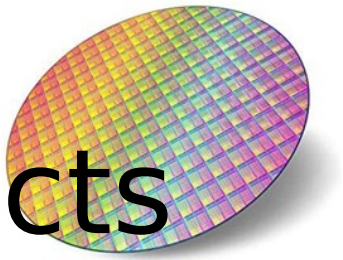
2020 Inrush Current Limiter in Hearing Aids

Ultra low power linear regulator

Linear Regulator for Audio Application

+ numerous special courses

Analog IC design courses – PhD & Industrial PhD projects



- Battery cell impedance spectroscopy and balancing using integrated switched-capacitor power converter
- Fully integrated DC-DC converter design in hearing aids' sound processors
- IC design for switched capacitor power converters
- Time-based control for power converters

Q & A