

Analog Circuits

- Transistor level
 - devices and circuits
 - low level of abstraction
 - SPICE simulation
- Macro level
 - larger blocks and systems
 - high level of abstraction
 - behavioural simulation (Matlab, VHDL/Verilog-AMS)

La Trobe University

INTEGRATED CIRCUIT DESIGN

week 12

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Analog Devices

- Passive
 - resistor
 - capacitor
 - inductor
- Active
 - diode
 - transistor
 - bipolar: NPN, PNP
 - FET: NMOS, PMOS

Scope

- Analog circuits

Analog Devices

- Resistors
 - large area utilisation
 - temperature coefficient
 - voltage coefficient
 - high value tolerance
 - resistor matching ratio may reach down to 0.1%
 - avoided in digital circuits

IC Design

- Digital circuits
 - functionality and complexity continuously increase
 - cost decrease
 - functionality/cost ratio increases
- Analog circuits
 - functionality/cost ratio remains constant
 - lower supply voltages limit functionality

Analog Devices

- MOSFET
 - low simulation accuracy for small signal analysis
 - use large signal model for operating point analysis
 - use large signal model for non-linear analysis
 - complex models
 - manufacturing process variations

Analog Devices

- Resistors
 - careful layout required
 - serpentine layout for larger values
 - place devices symmetrically
 - use MOSFET as resistor
 - voltage dependent
 - small area utilisation

Analog Devices

- MOSFET
 - different operation regions
 - $V_{gs} < V_{th}$ weak inversion
 - $V_{gs} > V_{th}$ strong inversion
 - $V_{ds} < V_{gs} - V_{th}$ linear
 - $V_{ds} > V_{gs} - V_{th}$ saturation

Analog Devices

- Capacitors
 - two classes
 - high accuracy
 - high capacitance
 - may require optional technology process
 - 2 poly layers for poly to poly capacitors

Analog Circuits

- Noise
 - proportional to temperature and bandwidth
- Signal to Noise Ratio (SNR)
 - proportional to $(V_{dd})^2$

Analog Devices

- Capacitors
 - gate or junction
 - large capacitance
 - high voltage and temperature coefficient
 - poly to poly
 - medium capacitance
 - low voltage and temperature coefficient
 - metal to metal
 - low capacitance
 - low voltage and temperature coefficient

Analog Circuits

- Operational amplifier issues
 - feedback and compensation
 - linear settling time
 - offset

Analog Circuits

- Noise sources
 - signal coupling
 - device thermal noise
 - flicker noise (from the manufacturing process)
 - sampling noise (in mixed circuits)

Analog Circuits

- Comparator
 - convert analog to digital signal
 - similar to an operational amplifier
 - metastability errors

Analog Circuits

- Circuit elements
 - emitter/source follower
 - differential stage
 - current generator
 - current mirror
 - cascode
 - common emitter/source (open drain/collector)

Analog Circuits

- Characteristics
 - gain
 - small and large signal bandwidth
 - gain-bandwidth product (GBW)
 - slew rate
 - common mode rejection ration (CMRR)
 - power supply rejection ratio (PSRR)

Analog Circuits

- Operational amplifier
 - input stage (differential)
 - voltage gain stage (common emitter/source)
 - current gain stage (emitter/source follower)

Analog Layout

- Noise coupling
 - shield critical nets
 - use differential nets
 - shield noise generators
 - separate analog and digital as much as possible

Mixed Circuits

- Analog to Digital Converters
 - basic converter: a comparator
 - flash comparator
 - many parallel comparators
 - successive approximation (SAR) converter
 - pipeline converter
 - ADC, DAC and adder
 - sigma delta converter
 - complex structure:
 - 1-bit DAC, adder, loop filter, comparator, digital filter

Analog Layout

- Thermal noise
 - use an RC network if possible to reduce noise

Analog Layout

- Special considerations for Analog and Mixed Circuits
 - design partitioning and floorplaning
 - separate power supplies and references
 - additional supply filtering
 - shielding

Analog Layout

- Matching
 - use the same W and L
 - use common centroid layout to minimise oxide and doping gradients
 - use dummy transistors at row ends to minimise poly etch loading and mask misalignment effects
 - use plenty of well and substrate taps
 - make clean and balanced routing