混合訊號與射頻積體電路實作

楊清淵副教授
許恆銘副教授
江衍忠助理教授
林維亮助理教授
What in the papers?

- New concepts
- New designs
- Improvements
- New applications
- ...
- How about failure? Rare~

Work successfully
What cause designs fail?

- Process variation
- Model accuracy
- Operation conditions
  - Temperature, humidity, EMI...
- Bad design (√)
- ...

Minimize design iteration

- **For foundry**
  - Offer accurate device models
  - Active devices: corner models, Monte Carlo models
  - Passive devices: variation ranges

- **For designer**
  - Current-biased scheme for analog/RF ICs
  - Simulate circuits with most conditions (worst-case simulation)
  - Add design margin to overcome process variations
  - Better circuit architectures to overcome process variations
  - Learn trouble shooting
Learn from failed designs

- ESD
- Latch-up
- Current density
- DC, AC
- What is the physical structure?
- ...

...
Design ABC

- Never ignore the DC simulation
  - Check every devices’ operation conditions

TT case

Corner case

\[ V_{DS} = 0.27V \]

\[ V_{DS} = 0.17V \]
Design ABC

- AC

Impedance = \frac{1}{j\omega C_c}

\[
R_D \quad C_L \quad R_L
\]

\[
C_c \quad R_s
\]
DC vs. Transient

- **DC simulation**: 3.5mA
DC vs. Transient

- Transient current: 25mA!
Symbol ≠ Physical structure

- NMOS

- Substrate
Between the schematic and reality
Case study

- Bandgap circuit

\[ I_1 + I_2 \rightarrow \text{constant to } T \]

\[ I_1 \alpha T \]

\[ R_1 \]

\[ I_2 \alpha \frac{1}{T} \]

Off-chip
Case study

- Reality

\[ R_1 \quad R_2 \]

0.15V @ on-chip GND
0V @ global GND

10mA
20mA
10mA
100μA
20mA
10mA
Bypass capacitor for single-ended circuit!
Bypass capacitor

- Relatively not important in diff. circuit

Virtual GND
On-board measurement

Properly modeled?

What equivalent?
How the current flows?

- **PA case**

![Diagram of PA case]
Current density

Is it wide enough?
Output buffers

- For quadrature outputs
How to fix it?

- Laser cut
- FIB
- Layout issue
- ...

[Diagram of a circuit or mechanical component with an arrow indicating a point of interest]
What else…

- DC probing pad
- Dummy circuit
- Self-test circuit
- Self-calibration circuit
- Robust design
- Read technical document carefully