Substrate bounce in mixed-mode CMOS IC’s

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contents

• substrate noise in CMOS
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substrate noise in CMOS

substrate is low-Ohmic! 10m\(\Omega\)cm
- digital Vss is tied to substrate: Vssd=Vsub
- digital logic draws peak currents
- PCB ground is not available on-chip (due to L_{bondwire})
substrate voltage

\[ V_{\text{sub}} = L \frac{dI}{dt} \]
problems in analog:

- coupling
- out band
- sampling
- demodulation

- guardrings don't help
example: current mirror

\[ V_T \text{ modulation} \]
connect Vssa to substrate
Cascodes must also follow the substrate
strategy for analog

- Connect analog Vss to dirty substrate
- NMOS: for DC current sources
- PMOS: for signal handling
- Use differential signals
- Use shielding for non-substrate related signals
Vssa=substrate=Vssd
analog signals referred to outside clean PCB ground
Examples

OTA

Examples

OTA

Examples

OTA
What about the N-well connection?

for signals referred to clean (PCB) ground
Take care for series R!

clean voltage

shielding

“clean” signal

dirty substrate

nwell

R
bandgap: wrt analog PCB ground
bandgap: wrt analog PCB ground

simulation

Nwell @ V_{dd}

Nwell @ source
bandgap: wrt dirty substrate
bandgap: wrt dirty substrate

simulation

Nwell @ source

Nwell @ V_{dd}
bandgap: experimental results

V_{\text{ref}} [V]

clock frequency [MHz]
current controlled oscillator:
signals referred to clean PCB ground
Vss=substrate=dirty
Inoise must be delivered by (non-linear) gm stage

- \( I_{\text{noise}} \) must be delivered by (non-linear) gm stage
- \( V_{\text{noise}} = \frac{I_{\text{noise}}}{gm} \) at input
- compensation
- linearisation
opamp testchip:
experimental results:

![Diagram of a circuit symbol with labels: out and vssa]

**PSRR simulation**

**PSRR measurement**

![Graphs showing PSRR simulation and measurement]
conclusions

- connect analog Vss to dirty substrate
- analog signals referred to clean PCB ground
- NMOS as DC current source
- PMOS for signal handling
- Differential signals
- Watch out for the well connection
- shielding
- Compensation
- Linearisation