Advanced Analog Integrated Circuits

Part II

Bernhard E. Boser
University of California, Berkeley

boser@eecs.berkeley.edu

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Implementation Issues

- Biasing
- Interference
- Practical OTA architectures
- MOS Switches
- Matching
- Precision Techniques
- Physical Layout

Depending on requirements, a different subset is relevant for a particular design. Conceptual design (Part I) largely unaffected.
Transistor Biasing

- Design Parameter
  - $g_m$, $V^*$, $f_T$
- Layout Parameter
  - $W$, $L$
  - Fingers $F$
  - Multiplicity $M$
Example

Design:
\[ g_m := 1\text{mS} \quad V_{\text{star}} := 120\text{mV} \quad f_T := 6\text{GHz} \]

Layout (lookup):
\[ W := \frac{I_D}{I_{d,w}} = 12\mu\text{m} \]
\[ I_D := 0.5 \cdot g_m \cdot V_{\text{star}} = 60\mu\text{A} \]
\[ I_{d,w} := 5 \frac{\text{A}}{\text{m}} \]
\[ L_w := 250\text{nm} \]

Spectre Syntax:
\texttt{op1 dc oppoint=screen}
Operating Point Analysis

Instance: M1 of nmos3
Model: nfet.4
Primitive: bsim3v3

d : V(v_ds) = 523.447 mV

g : V(v_gs) = 523.447 mV

s : val(0) = 0

b : val(0) = 0

type = n

region = sat

reversed = no

ids = 60.037 uA

isub = 41.0222 aA

vgs = 523.447 mV

vds = 523.447 mV

vbs = 0 V

vgb = 523.447 mV

vdb = 523.447 mV

vgd = 1.32916 pV

vth = 502.512 mV

vdsat = 78.9438 mV

vfbeff = -1.00379 V

\[ gm = 1.00019 \text{ mS} \]

\[ gds = 18.5458 \text{ uS} \]

\[ gmbs = 283.567 \text{ uS} \]

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Current Sources

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University of California, Berkeley
boser@eecs.berkeley.edu

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Current Source Realization: Mirror

Choices for $I_{ref}$: resistor, bandgap, constant $g_m$ reference, …
Cascode Bias

\[ \begin{align*}
&V_{\text{GS6}} \\
&V_1^* \\
&\text{M}_6 \quad 10\mu/180n \\
&\text{M}_5 \quad W/180n \\
&\text{M}_4 \quad 10\mu/180n \\
&\text{M}_3 \quad 10\mu/180n \\
&\text{M}_2 \quad 10\mu/180n \\
&\text{M}_1 \quad 10\mu/180n \\
\end{align*} \]
Bias Network Power Dissipation

\[ I_{\text{ref}} \]

\[ M_3 \]

\[ M_2 \]

\[ M_1 \]

\[ v_i \]

\[ v_o \]
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Noise

Bernhard E. Boser
University of California, Berkeley
bosер@eeecs.berkeley.edu

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Noise
Low Noise Current Source

Active (BJT or MOS)  

\[ I_0 \quad + \quad M_1 \quad V^* \quad - \]

Resistor  

\[ I_0 \quad + \quad V_R \quad - \]
Class of Operation

- **Class A ↔ focus in this course**
  - Constant bias current – runs continuously (e.g. even without signal)
  - (Nominally) constant $g_m$, pole frequencies
  - Poor power efficiency

- **Class B**
  - Bias current matches signal amplitude
  - No current when signal amplitude is zero
  - Usually high distortion

- **Class AB**
  - Class B with (small) quiescent current continuously running
  - Reduced distortion (compared to class B)
  - Used in output stages and buffers

- **Class D**
  - PWM “digital” output
  - Very high power efficiency
  - E.g. audio amplifiers

- ...