Lecture 33

• Last time:
  – Frequency response of voltage and current buffers
  – Voltage/Current sources using MOS transistors

• Today:
  – Improved current sources
  – Current mirrors

BIST MOSFET  PN Junction  R

Bode plots  Phasors  Small-signal

Single stage amps

2-port Pin. Port

DC sources  Voltage, Current

Multi-stage amps  Phasing, freq. response e.t.c.
Multi-Stage Amplifiers: Chap. 9

First topic: voltage and current sources (9.4)

- Generating a voltage: use a current source to set \( V_{GS} \) (or \( V_{BE} \)).
- Typical operating point: \( i_{OUT} = 0 \text{ A} \)

Modeling the Voltage Source

Find \( i_{OUT} \) versus \( V_{OUT} \)

\[
0 = i_{D,SAT} - I_{REF} = \mu \frac{W}{2L}(V_{GS} - V_{TH})^2 - I_{REF}
\]

\( V_{TH} = 0 \text{ V} \)
$I_T = \frac{V_{DS} - V_{TH}}{R_L}$

$V_{OUT} = \frac{V_{DS} - V_{TH}}{\sqrt{2L}} \frac{I_{OUT}}{R_L}$

Small-Signal Source Resistance

$R_S = \left( \frac{\partial I_{OUT}}{\partial V_{OUT}} \right)_{I_{OUT} = 0}$

Equivalent Circuit:

$V_{S} + \frac{V_{DS} - V_{TH}}{R_L}$

$\frac{dV_{OUT}}{dt} = \frac{V_{OUT}}{R_S}$

$R_S = \frac{V_{DS} - V_{TH}}{R_L}$
Using a Voltage Source to Make a Current Source

VDD

Rest of Circuit

VOUT

Rest of Circuit

VREF

M1

M2

IRef

VDD
Equivalent Circuit for I-Source

Find the DC current for "gray circle" equivalent circuit

\[ I_{\text{OUT}} = \frac{\mu n C}{2} \left( V_{\text{REF}} - V_n \right)^2 \]

Substitute for \( V_{\text{REF}} \)

Small-Signal Resistance of I-Source

[Diagram with annotations]