Frequency responses of CMOS amplifiers

- Capacitances of MOS transistors
- Bandwidth limitations
  - Frequency response of common-source amplifiers, dominant pole concept
  - BW estimation using Zero-Value Time-Constant (ZVTC) techniques
  - BW improvements via circuit design techniques
- Evaluation of frequency responses using NEET technique
- Frequency responses and compensation of feedback amplifiers
MOS transistor capacitances:
(1) pn-junction capacitances

\[ C_{sb} = \frac{C_{sbo}}{\sqrt{1 + \frac{V_{SB}}{\psi_o}}} \]

\[ C_{db} = \frac{C_{dbo}}{\sqrt{1 + \frac{V_{DB}}{\psi_o}}} \]
Junction capacitances as functions of AS, PS, AD, PD

*.subckt NM D G S B
+params: W=10u L=1u
M1 D G S B NM L={L} W={W} \nS={2*(2u+V)} PS={2*(2u+V)} \nAD={2*(2u+V)} PD={2*(2u+V)}
.ends

*                   * NMOS transistor model
*                   * MODEL NM NMOS LEVEL=8
*                   * SIMULATION PARAMETERS ***************
*                   * format : LTspice
*                   * model  : NMOS BSIM3v3
*                   * TYPICAL HEAT CONDITION
*                   * *** Flags ***
+MODNOD =1.000e+00 CAPNOD =2.000e+00
+MODMOD =3.000e+00
*                   * *** Threshold voltage related model parameters ***
+K1 =5.029e+01
+K2 =3.395e+02 K3 =-1.136e+00 K3B =-4.399e+01
+MCH =2.611e+17 UTH0 =4.979e+01
+UVFF =8.925e+02 DUT0 =5.000e+01 DUT1 =-1.039e+00
+DUT2 =8.375e+03 KETA =2.032e+02
+PSRF1 =3.51e+08 PSRF2 =7.401e-05

ECEN4827/5827 Analog IC Design
MOS transistor capacitances:
(2) Gate-to-Source capacitance

\[ C_{gs} = C_{overlap} + C_{gate-to-channel} \]

\[ C_{overlap} = C_{ol} \times W \]

\[ C_{gate-to-channel} = \frac{2}{3} C_{ox} \times W \times L \]

\[ C_{gs} \approx C_{gate-to-channel} = \frac{2}{3} C_{ox} WL \]

\[ C_{ol} = \Delta \times C_{ox} \]
MOS transistor capacitances:
(3) Gate-to-Drain capacitance

\[ C_{ol} = \Delta \times C_{ox} \]

\[ C_{gd} = C_{overlap} = C_{ol} W \]
MOS transistor model with capacitances
0.35μm CMOS process: approximate models for hand calculations

\[ \begin{align*}
C_{gs} & \approx [3 \text{ fF}/(\mu\text{m})^2]\cdot W\cdot L \\
C_{gd} & \approx [0.3 \text{ fF}/(\mu\text{m})]\cdot W \\
C_{db} & \approx [1.5 \text{ fF}/(\mu\text{m})]\cdot W \\
C_{sb} & \approx [1.5 \text{ fF}/(\mu\text{m})]\cdot W + [0.75 \text{ fF}/(\mu\text{m})^2]\cdot W\cdot L
\end{align*} \]

\[ \begin{align*}
C_{gs} & \approx [3 \text{ fF}/(\mu\text{m})^2]\cdot W\cdot L \\
C_{gd} & \approx [0.15 \text{ fF}/(\mu\text{m})]\cdot W \\
C_{db} & \approx [2.5 \text{ fF}/(\mu\text{m})]\cdot W \\
C_{sb} & \approx [2.5 \text{ fF}/(\mu\text{m})]\cdot W + [1.25 \text{ fF}/(\mu\text{m})^2]\cdot W\cdot L
\end{align*} \]

Beware: do not expect very accurate results using hand calculations, especially for short channel lengths (L < 2 μ)
$f_T$ of MOS transistors
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CS amplifier frequency responses

\[ +V_{DD} \]

\[ M_2 \]
\[ M_3 \]

\[ R_{in} \]

\[ M_1 \]

\[ V_I + v_i \]

\[ V_O + v_o \]

\[ C_L \]
CS amplifier small-signal model
CS amplifier frequency response
CS amplifier frequency response
CS amplifier frequency response
CS amplifier frequency response