MOST PARASITIC CAPACITANCES

Figure 1. Parasitic capacitances of mos transistor.

Parasitic Capacitors in MOS Transistors, shown for p-channel device

Figure 1. Parasitic capacitances of mos transistor.
MOST Oxide Capacitances

$C_{OX}$ is the controlling capacitance of the MOST device. It gives rise to three capacitances:

- an overlap capacitance between gate and source $C_{GSO}$
- a gate to channel capacitance $C_{GC}$
- an overlap capacitance between gate and drain $C_{GDO}$

The overlap capacitances are a result of the gate overlapping source and drain by an amount $LD$ (see Figure 1). The corresponding capacitances $C_{GSO}$ and $C_{GDO}$ are calculated as follows:

\[ C_{GSO} = CGSO \times W \]
\[ C_{GDO} = CGDO \times W \]

However, the overlap $LD$ is never known precisely and therefore, in the SPICE parameters list, the parameters $CGSO$ and $CGDO$ are given in Farad per meter with channel width $W$, as design parameter.

It is obvious that $C_{GSO}$ is directly added to terminal capacitance $C_{GS}$ and that $C_{GDO}$ is added to $C_{GD}$.

The contribution of the gate-to-channel to the terminal capacitances depends on the operation region of the device. Its total value is

\[ C_{GC} = C_{OX} \times W \times L_{eff} \]

In the ohmic region, $C_{GC}$ occurs between the gate and the channel, which connects source and drain and its value is even split between the terminal capacitances $C_{GS}$ and $C_{GD}$.

\[ C_{GS} = C_{GSO} + \frac{1}{2} C_{GC} \]
\[ C_{GD} = C_{GDO} + \frac{1}{2} C_{GC} \]

In the saturation region, however, the channel is discontinued at the drain end. Most of the capacitance $2/3 \ C_{GC}$ is added to the source terminal capacitance and nothing is added to $C_{GD}$.
\[ \begin{align*}
C_{GS} &= C_{GSO} + 2/3 \ C_{GC} \\
C_{GD} &= C_{GDO}
\end{align*} \]

**MOST Junction Capacitances**

The source-channel-drain structure is isolated from the substrate by junction space charge depletion layers. Therefore, three junction capacitances are:

- the channel-bulk (or substrate) junction capacitance \( C_{BC} \)
- the source-bulk junction capacitance \( C_{BS} \)
- the drain-bulk junction capacitance \( C_{BD} \)

The channel-bulk junction capacitance \( C_{BC} \) is the controlling capacitance like \( C_{GS} \) in the oxide capacitance. Its total value is

\[ C_{BC} = C_{BCj} W L_{\text{eff}} \]

In the calculation, \( V_{BC} = V_{BS} \) in order to obtain a worst case value.

The capacitance \( C_{BC} \) is divided over the terminal capacitances \( C_{BS} \) and \( C_{BD} \) in very much the same way as \( C_{GC} \) is divided over \( C_{GS} \) and \( C_{GD} \).

The source-bulk and drain-bulk junction capacitances consist of a bottom plate capacitance and a side wall capacitance. All values depend on the respective junction voltages.

\[ C_{BSj} = \frac{C_j}{\left(1 - \frac{V_{BS}}{\phi_B}\right)^{nj}} \]

\[ C_{BSjw} = \frac{C_{jw}}{\left(1 - \frac{V_{BS}}{\phi_B}\right)^{njw}} \]

\[ C_{BSO} = A_S C_{BSj} + P_S C_{BSjw} \]
\[ C_{BDj} = \frac{C_j}{\left(1 - \frac{V_{BD}}{\phi_B}\right)^{m_j}} \]
\[ C_{BDjsw} = \frac{C_{jsw}}{\left(1 - \frac{V_{BD}}{\phi_B}\right)^{m_{jsw}}} \]

\[ C_{BDO} = A_D C_{BDj} + P_D C_{BDjsw} \]

In the ohmic region

\[ C_{BS} = C_{BSO} + \frac{1}{2} C_{BC} \]
\[ C_{BD} = C_{BDO} + \frac{1}{2} C_{BC} \]

In the saturation region,

\[ C_{BS} = C_{BSO} + \frac{2}{3} C_{BC} \]
\[ C_{BD} = C_{BDO} \]
Figure 2. NMOS transistor: (a) layout, (b) terminal parasitic capacitances.
*SCNA20 Orbit 2u technology Spice Parameters

.MODEL CMOSN NMOS LEVEL=1 PHI=0.600000 TOX=4.1000E-08
XJ=0.200000U TPG=1
+ VTO=0.8630 DELTA=6.6420E+00 LD=2.4780E-07 KP=4.7401E-05
+ UO=562.8 UEXP=1.5270E-01 UCRIT=7.7040E+04 RSH=2.4000E+01
+ GAMMA=0.4374 NSUB=4.0880E+15 NFS=1.980E+11 NEFF=1.0000E+00
+ VMAX=5.8030E+04 LAMBDA=3.1840E-02 CGDO=3.1306E-10
+ CGSO=3.1306E-10 CGBO=4.3449E-10 CJ=9.5711E-05 MJ=0.7817
+ CJSW=5.0429E-10 MJSW=0.346510 PB=0.800000

* Weff = Wdrawn - Delta_W
*The suggested Delta_W is -5.4940E-07

\[ \varepsilon_0 = 8.86 \times 10^{-14} \text{ F/cm} = 8.86 \times 10^{-18} \text{ F/\mu m} = 0.00886 \text{ fF/\mu m} \]
LD = 0.2478 \mu m \approx 0.25 \mu m
L_{eff} = L - 2LD = 10 - 2(0.25) = 9.5 \mu m
W = 15 \mu m
CGSO = CGDO = 3.13 \times 10^{-10} \text{ F/\mu m} = 0.313 \text{ fF/\mu m}
C_j = 9.57 \times 10^{-5} \text{ F/\mu m}^2 = 0.0957 \text{ fF/\mu m}^2
mj = 0.7817
C_{jsw} = 5.0429 \times 10^{-10} \text{ F/\mu m} = 0.50429 \text{ fF/\mu m}
mjsw = 0.34651
V_{BC} = V_{BS} = 0
V_{BD} = -5V

**MOST Oxide Capacitances**

\[ C_{ox} = \frac{\varepsilon_0}{T_{ox}} = \frac{3.9 \varepsilon_0}{T_{ox}} = \frac{3.9(8.86 \times 10^{-14} \text{ F/cm})}{4.1 \times 10^{-8} \text{ m}} = \frac{3.9(0.00886 \text{ fF/cm})}{4.1 \times 10^{-2} \text{ \mu m}} = 0.843 \text{ fF/\mu m}^2 \]

\[ C_{gc} = C_{ox} W L_{eff} = (0.843 \text{ fF/\mu m}^2)(9.5 \mu m)(15 \mu m) = 120 \text{ fF} \]

\[ C_{gso} = CGSO \cdot W = (3.13 \times 10^{-10} \text{ F/\mu m})(15 \mu m) = 4.7 \text{ fF} \]

\[ C_{gdo} = CGDO \cdot W = (3.13 \times 10^{-10} \text{ F/\mu m})(15 \mu m) = 4.7 \text{ fF} \]

**Ohmic Region**

\[ C_{gs} = C_{gso} + \frac{1}{2} C_{gc} = 4.7 \text{ fF} + \frac{1}{2}(120 \text{ fF}) = 64.7 \text{ fF} \]

\[ C_{gd} = C_{gdo} + \frac{1}{2} C_{gc} = 4.7 \text{ fF} + \frac{1}{2}(120 \text{ fF}) = 64.7 \text{ fF} \]

**Saturation Region**
\[ C_{GS} = C_{GSO} + \frac{2}{3} C_{GC} = 4.7 \text{fF} + \frac{2}{3} (120 \text{fF}) = 84.7 \text{fF} \]

\[ C_{GD} = C_{GDO} = 4.7 \text{fF} \]

**MOST Junction Capacitances**

\[
C_{BCj} = \left( \frac{C_j}{1 - \frac{V_{BC}}{\phi_B}} \right)_{mj} = \frac{C_j}{1 - \frac{V_{BS}}{\phi_B}}_{mj} = \frac{9.57 \times 10^{-5} \text{F/m}^2}{0.7817} = \frac{0.957 \text{fF/\mu m}^2}{0.7817} = 0.957 \text{fF/\mu m}^2
\]

\[
C_{BC} = C_{BCj} W L_{\text{eff}} = (0.957 \text{fF/\mu m}^2) (15 \mu \text{m})(9.5 \mu \text{m}) = 13.64 \text{fF}
\]

\[
C_{BSj} = \left( \frac{C_j}{1 - \frac{V_{BS}}{\phi_B}} \right)_{mj} = \frac{9.57 \times 10^{-5} \text{F/m}^2}{0.7817} = \frac{0.957 \text{fF/\mu m}^2}{0.7817} = 0.957 \text{fF/\mu m}^2
\]

\[
C_{BSjw} = \left( \frac{C_{jw}}{1 - \frac{V_{BS}}{\phi_B}} \right)_{mjw} = \frac{5.0429 \times 10^{-10} \text{F/m}}{0.34651} = \frac{0.50429 \text{fF/\mu m}}{0.34651} = 0.50429 \text{fF/\mu m}
\]

\[
C_{BSO} = A_s C_{BSj} + P_s C_{BSjw} = (150 \mu \text{m}^2)(0.957 \text{fF/\mu m}^2) + (50 \mu \text{m})(0.50429 \text{fF/\mu m}) = 39.57 \text{fF}
\]

\[
C_{BDj} = \left( \frac{C_j}{1 - \frac{V_{BD}}{\phi_B}} \right)_{mj} = \frac{9.57 \times 10^{-5} \text{F/m}^2}{0.7817} = \frac{0.957 \text{fF/\mu m}^2}{0.7817} = 0.0203 \text{fF/\mu m}^2
\]

\[
C_{BDjw} = \left( \frac{C_{jw}}{1 - \frac{V_{BD}}{\phi_B}} \right)_{mjw} = \frac{5.0429 \times 10^{-10} \text{F/m}}{0.34651} = \frac{0.50429 \text{fF/\mu m}}{0.34651} = 0.2539 \text{fF/\mu m}
\]
\[ C_{	ext{BSO}} = A_{D} C_{	ext{BDj}} + P_{D} C_{	ext{BDjsw}} \]
\[ = (90 \mu m^2)(0.0203 \text{fF/\mu m}^2) + (42 \mu m)(0.2539 \text{fF/\mu m}) = 12.49 \text{fF} \]

Ohmic region:

\[ C_{\text{BS}} = C_{	ext{BSO}} + \frac{1}{2} C_{\text{BC}} = 39.5 \text{fF} + \frac{1}{2} (13.64 \text{fF}) = 46.39 \text{fF} \]

\[ C_{\text{BD}} = C_{	ext{BSO}} + \frac{1}{2} C_{\text{BC}} = 12.49 \text{fF} + \frac{1}{2} (13.64 \text{fF}) = 19.31 \text{fF} \]

Saturation region:

\[ C_{\text{BS}} = C_{	ext{BSO}} + \frac{2}{3} C_{\text{BC}} = 39.57 \text{fF} + \frac{2}{3} (13.64 \text{fF}) = 48.66 \text{fF} \]

\[ C_{\text{BD}} = C_{	ext{BSO}} = 12.49 \text{fF} \]

**Electrode Capacitor**

See Link to Layout of Capacitor

**Poly Resistor/HighRes Poly2 Resistor**

See Link to Layout of Resistor