MOST PARASITIC CAPACITANCES

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 $C_{GSO}$ and $C_{GDO}$ 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 $C_{GD}$.
$C_{GS} = C_{GSO} + \frac{2}{3} C_{GC}$

$C_{GD} = C_{GDO}$

**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

$$C_{BCj} = \frac{C_j}{\left(1 - \frac{V_{BC}}{\phi_B}\right)^{mj}}$$

$$C_{BC} = C_{BCj} W L_{eff}$$

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.

$$C_{BSj} = \frac{C_j}{\left(1 - \frac{V_{BS}}{\phi_B}\right)^{mj}}$$

$$C_{BSjw} = \frac{C_{jw}}{\left(1 - \frac{V_{BS}}{\phi_B}\right)^{mjw}}$$

$$C_{BSO} = A_S C_{BSj} + P_S C_{BSjw}$$
In the ohmic region

\[ C_{BDj} = \frac{C_j}{(1 - \frac{V_{BD}}{\phi_B})^{m_j}} \]

\[ C_{BDjsw} = \frac{C_{jsw}}{(1 - \frac{V_{BD}}{\phi_B})^{m_{jsw}}} \]

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

In the saturation 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=562.8UXEP=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 = .2478 \mu m \approx .25 \mu m

L_{\text{eff}} = L - 2LD = 10 - 2(.25) = 9.5 \mu m

W = 15 \mu m

CGSO=CGDO=3.13x10^{-10} \text{ F/m}=0.313 \text{ fF/\mu m}

C_j = 9.57x10^{-5} \text{ F/\mu m}^2 = 0.0957 \text{ fF/\mu m}^2

mj = .7817

C_{jsw} = 5.0429x10^{-10} \text{ F/m} = 0.50429 \text{ fF/\mu m}

mjsw = .34651

V_{BC}=V_{BS}=0

V_{BD}=-5V

MOST Oxide Capacitances

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

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

\[ C_{GSO} = CGSO \cdot W = (3.13x10^{-10} \text{ F/m})(15 \mu m) = 4.7 \text{ fF} \]

\[ C_{GDO} = CGDO \cdot W = (3.13x10^{-10} \text{ F/m})(15 \mu m) = 4.7 \text{ fF} \]

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

\[ \varepsilon_0 = 8.86 \times 10^{-14} \text{ F/cm} = 8.86 \times 10^{-18} \text{ F/\mu m} = 0.00886 \text{ fF/\mu m} \]

LD = .2478 \mu m \approx .25 \mu m

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V_{BC}=V_{BS}=0

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MOST Oxide Capacitances

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

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

\[ C_{GSO} = CGSO \cdot W = (3.13x10^{-10} \text{ F/m})(15 \mu m) = 4.7 \text{ fF} \]

\[ C_{GDO} = CGDO \cdot W = (3.13x10^{-10} \text{ F/m})(15 \mu m) = 4.7 \text{ fF} \]

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**

\[
C_{BCj} = \frac{C_j}{\left(1 - \frac{V_{BC}}{\phi_B}\right)} = \frac{C_j}{\left(1 - \frac{V_{BS}}{\phi_B}\right)} = \frac{9.57 \times 10^{-5} \text{F/m}^2}{0.7817} = \frac{0.0957 \text{fF/\mu m}^2}{0.0957 \text{fF/\mu m}^2}
\]

\[ C_{BC} = C_{BCj} \times \text{W} \times L_{\text{eff}} = (0.0957 \text{fF/\mu m}^2)(15 \mu \text{m})(9.5 \mu \text{m}) = 13.64 \text{fF} \]

\[
C_{BSj} = \frac{C_j}{\left(1 - \frac{V_{BS}}{\phi_B}\right)} = \frac{9.57 \times 10^{-5} \text{F/m}^2}{0.7817} = \frac{0.0957 \text{fF/\mu m}^2}{0.0957 \text{fF/\mu m}^2}
\]

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

\[ C_{BSO} = A_s C_{BSj} + P_s C_{BSjw} = (150 \mu \text{m}^2)(0.0957 \text{fF/\mu m}^2) + (50 \mu \text{m})(0.50429 \text{fF/\mu m}) = 39.57 \text{fF} \]

\[
C_{BDj} = \frac{C_j}{\left(1 - \frac{V_{BD}}{\phi_B}\right)} = \frac{9.57 \times 10^{-5} \text{F/m}^2}{0.7817} = \frac{0.0957 \text{fF/\mu m}^2}{0.0957 \text{fF/\mu m}^2}
\]

\[
C_{BDjw} = \frac{C_{jsw}}{\left(1 - \frac{V_{BDjw}}{\phi_B}\right)} = \frac{5.0429 \times 10^{-10} \text{F/m}}{0.34651} = \frac{0.50429 \text{fF/\mu m}}{0.50429 \text{fF/\mu m}}
\]
\[ C_{BDO} = A_D C_{BDj} + P_D C_{BDjeW} \]
\[ = (90 \mu m^2)(0.0203 fF/\mu m^2) + (42 \mu m)(0.2539 fF/\mu m) = 12.49 fF \]

Ohmic region:
\[ C_{BS} = C_{BSO} + \frac{1}{2} C_{BC} = 39.5 fF + \frac{1}{2}(13.64 fF) = 46.39 fF \]
\[ C_{BD} = C_{BDO} + \frac{1}{2} C_{BC} = 12.49 fF + \frac{1}{2}(13.64 fF) = 19.31 fF \]

Saturation region:
\[ C_{BS} = C_{BSO} + \frac{2}{3} C_{BC} = 39.57 fF + \frac{2}{3}(13.64 fF) = 48.66 fF \]
\[ C_{BD} = C_{BDO} = 12.49 fF \]

**Electrode Capacitor**

See [Layout of Capacitor](#)

**Poly Resistor/HighRes Poly2 Resistor**

See [Layout of Resistor](#)