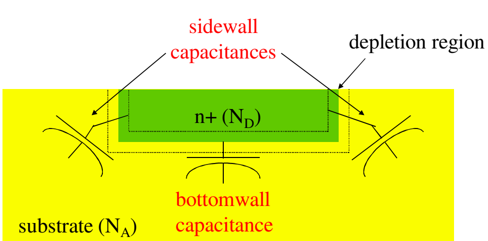
Wires

Wire parasitics

- Diffusion wire
- Poly and metal wires
- Wire-to-wire parasitics

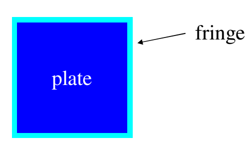
Diffusion wire capacitance

- Capacitances formed by p-n junctions:



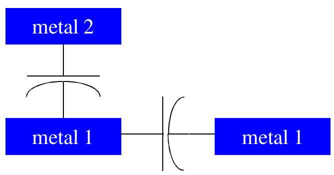
Poly/metal wire capacitance

- Two components:
  - parallel plate;
  - fringe.



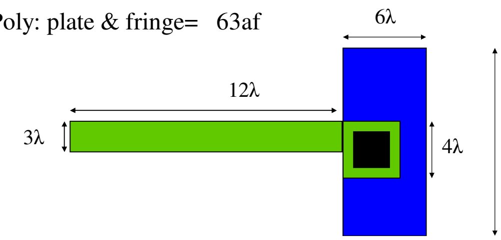
Metal coupling capacitances

- Can couple to adjacent wires on same layer, wires on above/below layers:



Example: parasitic capacitance measurement

- n-diffusion: bottom wall=940 aF/um^2, sidewall=200 aF/um.
- metal: plate=36 aF, fringe=54 aF.
- Poly: plate & fringe= 63af



N-diffusion layer capacitance calculation

- Bottom wall capacitance
  - Area of n-diffusion layer:
  - $3x12x\lambda^2 + 4x4\lambda^2 = 36\lambda^2 + 16\lambda^2 = 52\lambda^2 = 52(.09\mu m)^2 = 0.4212\mu m^2$
  - Bottom wall capacitance : 0.4212x940aF= 0.39fF
- Side wall capacitance:
  - Perimeter of side wall (counter clockwise)

$$0.27\mu m + 1.08\mu m + 0.09\mu m + 0.36\mu m + 0.36\mu m + 1.44\mu m = 3.6\mu m$$

  - Side wall capacitance: 3.6x200af = 0.72fF
- Total n-diffusion capacitance: 0.42 + 0.72 = **1.11fF**

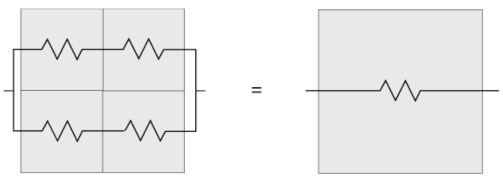
Typical parameters for our 180 nm process.

p-type transconductance	k'_p	$-30\mu A/V^2$	poly resistivity	R_{poly}	$8\Omega/\square$
n-type threshold voltage	V_{tn}	0.5V	metal 1-substrate plate capacitance	$C_{metal1,plate}$	$36aF/\mu m^2$
p-type threshold voltage	V_{tp}	-0.5V	metal 1-substrate fringe capacitance	$C_{metal1,fringe}$	$54aF/\mu m$
n-diffusion bottomwall capacitance	$C_{ndiff,bot}$	$940aF/\mu m^2$	metal 2-substrate capacitance	$C_{metal2,plate}$	$36aF/\mu m^2$
n-diffusion sidewall capacitance	$C_{ndiff,side}$	$200aF/\mu m$	metal 2-substrate fringe capacitance	$C_{metal2,fringe}$	$51aF/\mu m$
p-diffusion bottomwall capacitance	$C_{pdiff,bot}$	$1000aF/\mu m^2$	metal 3-substrate capacitance	$C_{metal3,plate}$	$37aF/\mu m^2$
p-diffusion sidewall capacitance	$C_{pdiff,side}$	$200aF/\mu m$	metal 3-substrate fringe capacitance	$C_{metal3,fringe}$	$54aF/\mu m$
n-type source/drain resistivity	R_{ndiff}	$7\Omega/\square$	metal 1 resistivity	R_{metal1}	$0.08\Omega/\square$
p-type source/drain resistivity	R_{pdiff}	$7\Omega/\square$	metal 2 resistivity	R_{metal2}	$0.08\Omega/\square$
poly-substrate plate capacitance	$C_{poly,plate}$	$63aF/\mu m^2$	metal 3 resistivity	R_{metal3}	$0.03\Omega/\square$
poly-substrate fringe capacitance	$C_{poly,fringe}$	$63aF/\mu m$	metal current limit	$I_{m,max}$	$1mA/\mu m$

- What will be metal wire capacitance?

Wire resistance

- Resistance of any size square is constant:

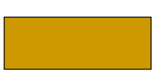


Skin effect

- At low frequencies, most of copper conductor's cross section carries current.
- As frequency increases, current moves to skin of conductor.
  - Back EMF induces counter-current in body of conductor.
- Skin effect most important at gigahertz frequencies.

Skin effect, cont'd

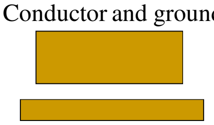
- Isolated conductor:



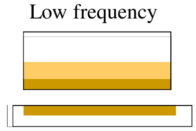
Low frequency

High frequency

- Conductor and ground:



Low frequency



High frequency

Skin depth

- Skin depth is depth at which conductor's current is reduced to 1/3 = 37% of surface value:

  $\delta = 1/\mathrm{sqrt}(\pi\ f\ \mu\ \sigma)$
  - f = signal frequency

  μ = magnetic permeability

  σ = wire conducitvity

Effect on resistance

- Low frequency resistance of wire:
  - $R_{dc} = 1/ \sigma wt$
- High frequency resistance with skin effect:
  - $R_{hf} = 1/2 \sigma \delta (w + t)$
- Resistance per unit length:
  - $R_{ac} = \mathrm{sqrt}(R_{dc}{}^2 + \kappa R_{hf}{}^2)$
- Typically $\kappa = 1.2$.