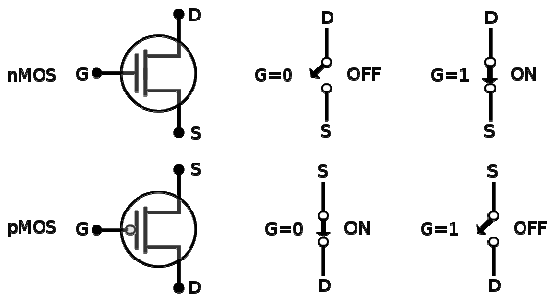
MOSFET



A Simple Transistor Model

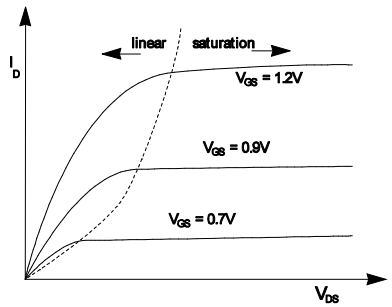
The variables that describe a transistor's behavior, are:

- *Vgs*—the gate-to-source voltage;
- *Vds*—the drain-to-source voltage (remember that *Vds* = -*Vsd*);
- *Id*—the current flowing between the drain and source.

The constants that determine the magnitude of source-to-drain current in the transistor are:

- V_t—the transistor threshold voltage, which is positive for an n-type transistor and negative for a p-type transistor;
- *k'*—the transistor transconductance, which is positive for both types of transistors;
- *W*/*L*—the width-to-length ratio of the transistor.

Drain current characteristics



Drain current

- Linear region ($V_{ds} < V_{gs} - V_t$):
  - $I_d = k' (W/L)[(V_{gs} - V_t)V_{ds} - 0.5 V_{ds}^2)]$
- Saturation region ($V_{ds} >= V_{gs} - V_t$):
  - $I_d = 0.5k' (W/L)(V_{gs} - V_t)^2$

	k'	V_t
n-type	$k'_n = 170\mu A/V^2$	$0.5V$
p-type	$k'_p = -30\mu A/V^2$	$-0.5V$

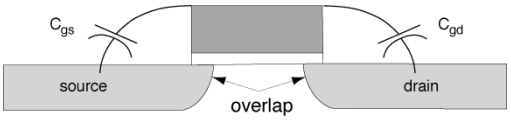
A minimum-size transistor in the SCMOS rules is of size $L = 2\lambda$ and $W = 3\lambda$. Given this size of transistor and the 180 nm transistor characteristics, calculate the current through a minimum-sized n-type transistor at the boundary between the linear and saturation regions at $V_{gs} = 0.7V$

$$I_d = \frac{1}{2}\left(170\frac{\mu A}{V^2}\right)\left(\frac{3\lambda}{2\lambda}\right)(0.7V\text{-}0.5V)^2 = 5.1\mu A$$

Basic transistor parasitics

1. Gate to substrate, also gate to source/drain.
2. Source/drain capacitance, resistance.
3. Gate capacitance C_g. Determined by active area.
4. Source/drain overlap capacitances C_{gs}, C_{gd}. Determined by source/gate and drain/gate overlaps. Independent of transistor L.
   - $C_{gs} = C_{ol}$ W
5. Gate/bulk overlap capacitance.

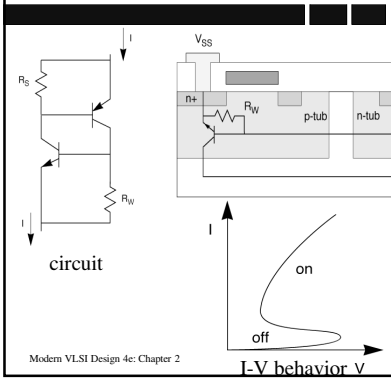
Transistor parasitics cntd..



Latch-up (parasitics in IC)

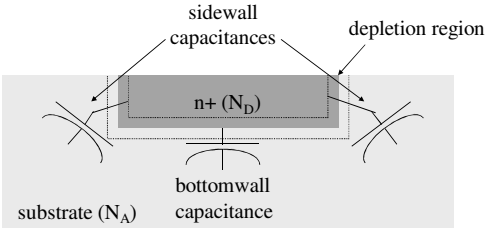
- CMOS ICs have parastic silicon-controlled rectifiers (SCRs).
- When powered up, SCRs can turn on, creating low-resistance path from power to ground. Current can destroy chip.
- Early CMOS problem. Can be solved with proper circuit/layout structures.

Parasitic SCR



Diffusion wire capacitance

- Capacitances formed by p-n junctions:



Quiz

Calculate the current through a minimum-sized p-type transistor at saturation.