### N-type MOSFET



### Zero-Order Model
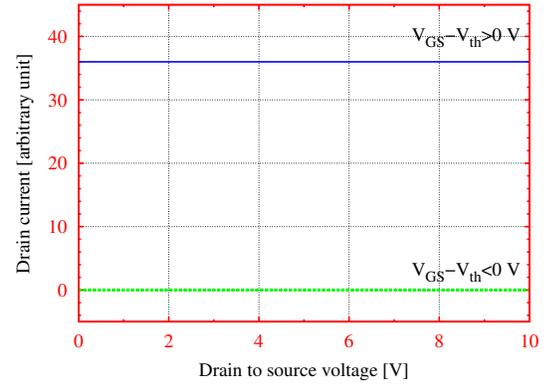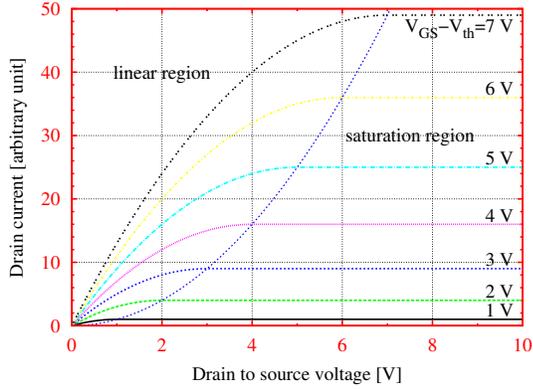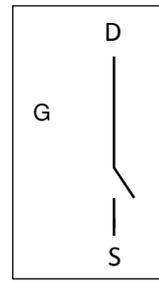






$I_{ds}$ unbounded when $V_{gs} > V_{th}$
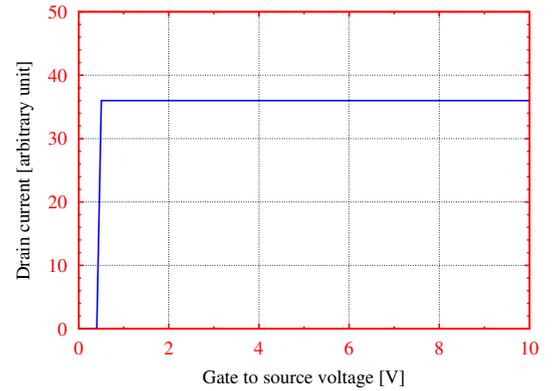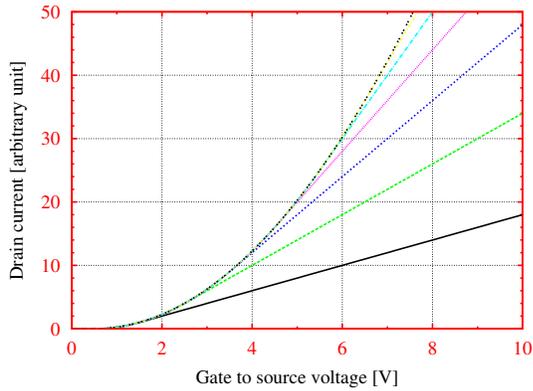


(even this is a simplified approximation)



Step at $V_{gs} = V_{th}$

|  | NMOS | PMOS |
|---|---|---|
| Threshold | $V_{thn} > 0$ | $V_{thp} < 0$ <br> $V_{thp} \approx -V_{thn}$ |
| Conduct | positive input <br> $V_{gs} > V_{thn}$ | negative input <br> $V_{gs} < V_{thp}$ |
| Drain | most positive terminal | most negative terminal |
| Source | most negative terminal <br> (source of electrons) | most positive terminal <br> (source of holes) |

$$V_{gs} = V_g - V_s \tag{1}$$

1) What function does this circuit implement? (inputs are $a$ and $b$)

[N.B. crossing wires with no dot are **not** connected.]
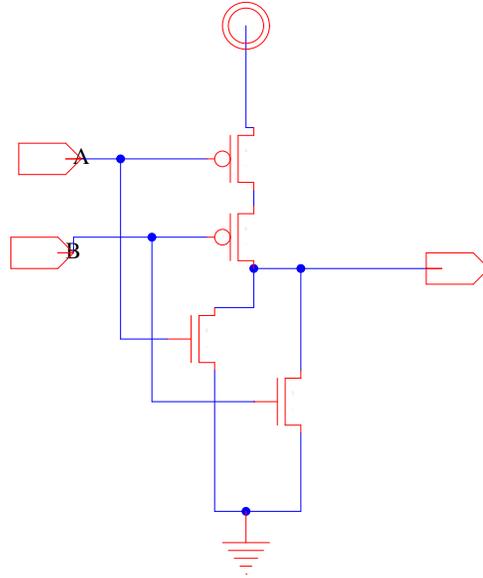
2) If $\overline{f} = a + b$, what is $f$ in minimum-sum-of-products form?

[N.B. $\overline{f} = \sim\!f = /f = (\text{not f}) = \text{f'}$]

**General form for Static CMOS Gate:**          3) Design gate to perform: $f = (\bar{a} + \bar{b}) \cdot \bar{c}$

Vdd

inputs

PMOS
Pullup
Network

out

NMOS
Pulldown
Network

Gnd

2