# CMOS Transistor Switching

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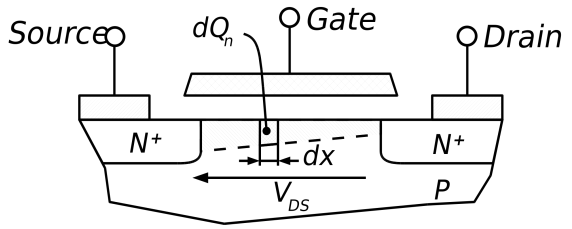
# Simple Transistor Model (1)

**Cutoff, subthreshold, or weak-inversion mode**

When $V_{GS} < V_t$:

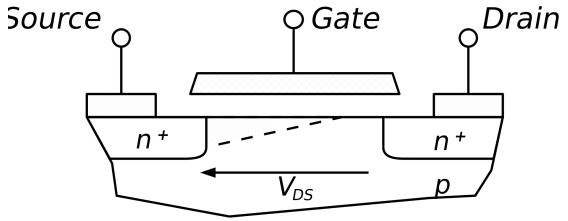
$$I_d = 0$$




**Triode mode or linear region (the ohmic mode)**

When $V_{GS} > V_t$ and $V_{DS} < (V_{GS} - V_t)$

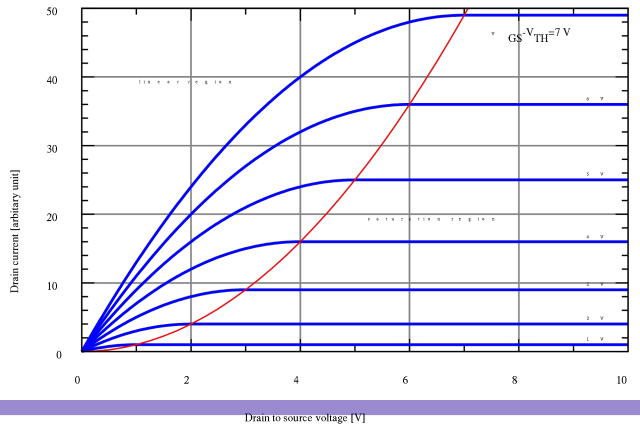
$$I_d = k' \frac{W}{L}\left[(v_{gs} - v_t)v_{ds} - \frac{1}{2}v_{ds}^2\right]$$




**Saturation or active mode**

When $V_{GS} > V_t$ and $V_{DS} \geq (V_{GS} - V_t)$

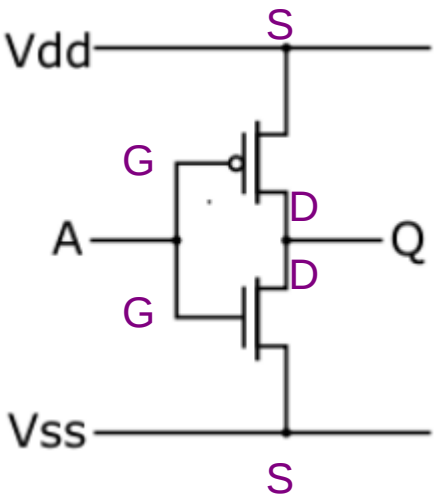
$$I_d = \frac{1}{2}k' \frac{W}{L}(v_{gs} - v_t)^2$$

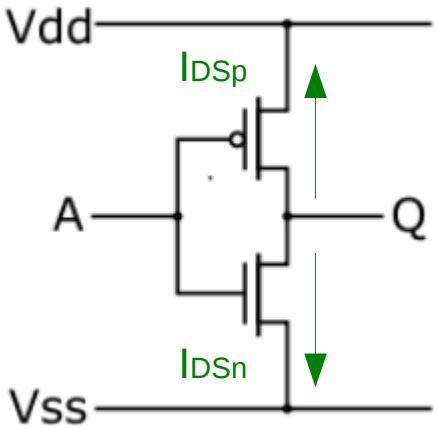


# Logic Level

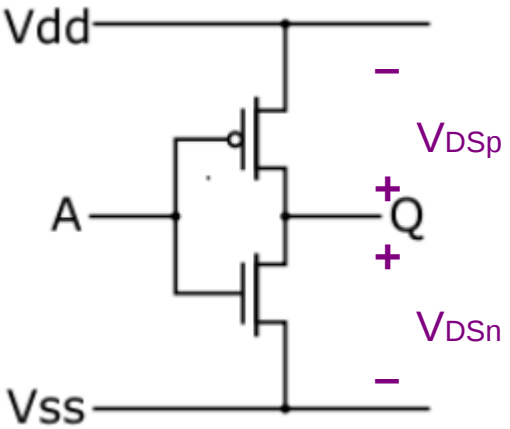
# Characteristic Curve

# Notation



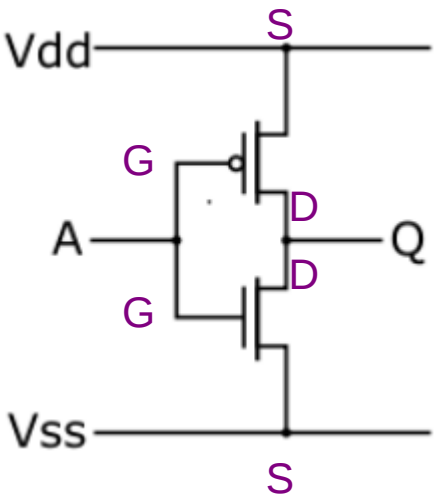



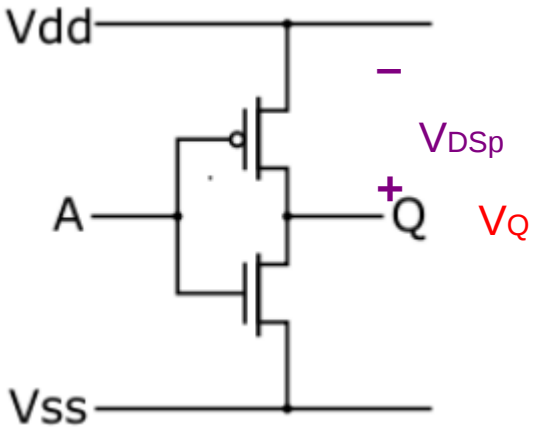

Current
Notation




Voltage
Notation

# Output Voltage

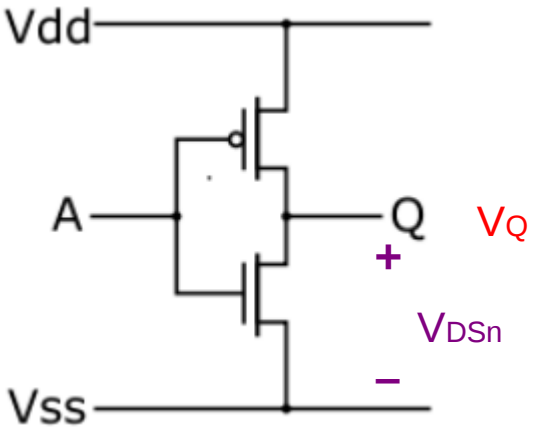



Voltage Notation

$$V_Q = V_{DSp} + V_S$$

$$= V_{DSp} + V_{dd}$$

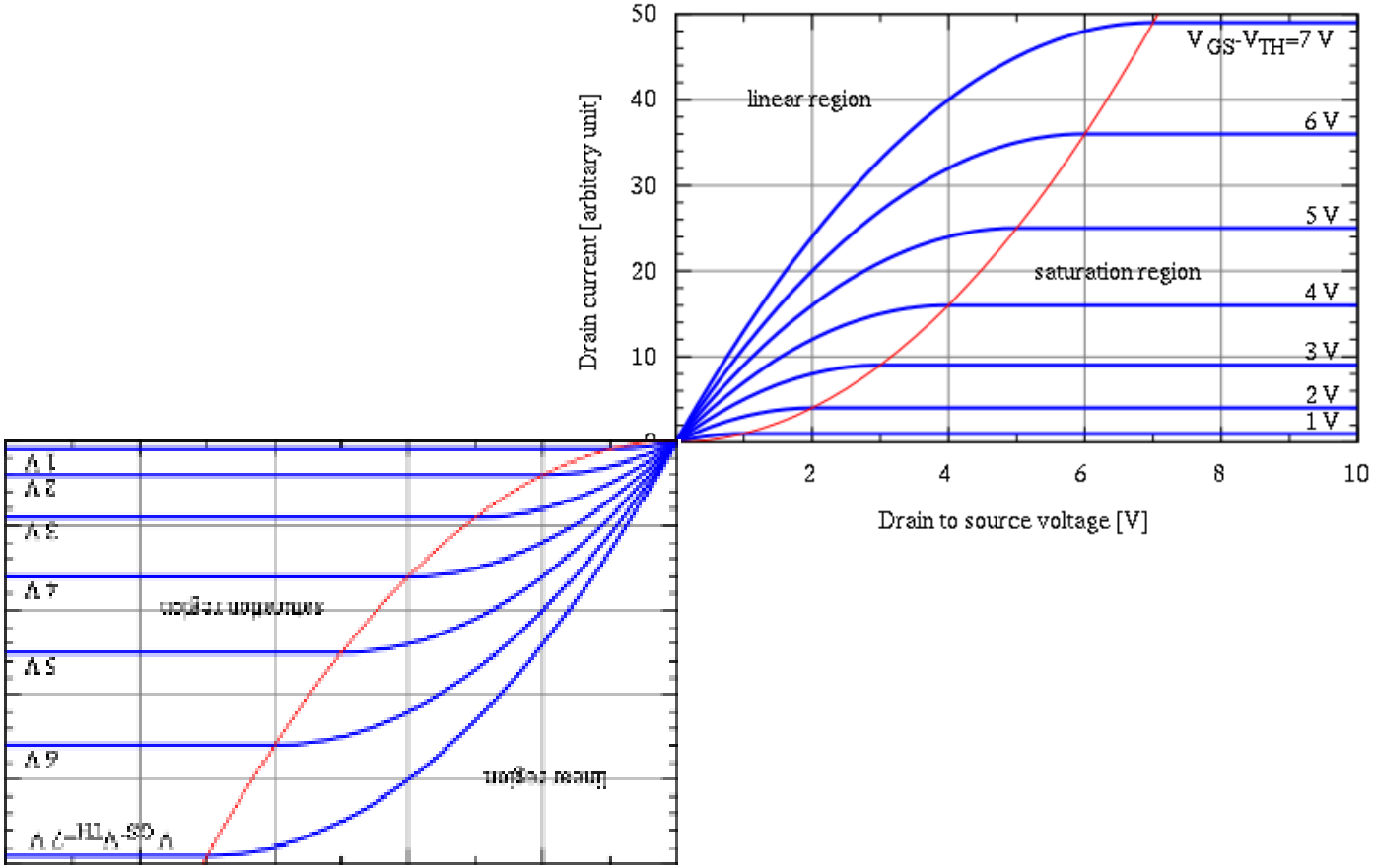



Voltage Notation

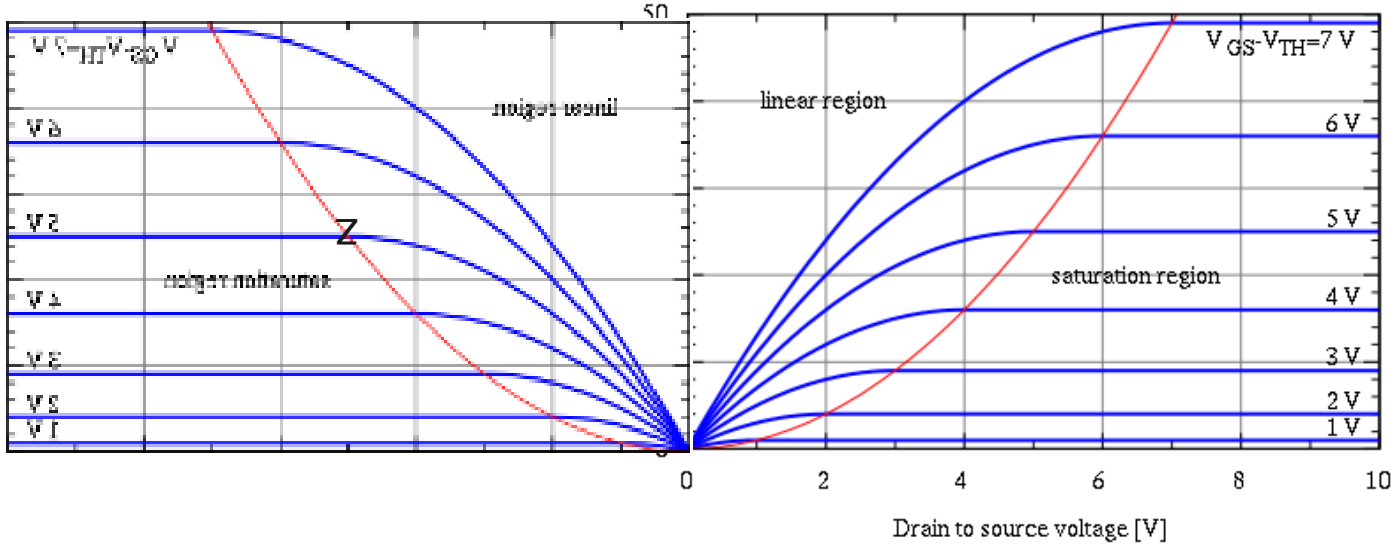
$$V_Q = V_{DSn} + V_S$$

$$= V_{DSn} + V_{ss}$$

# Characteristic Curves (1)

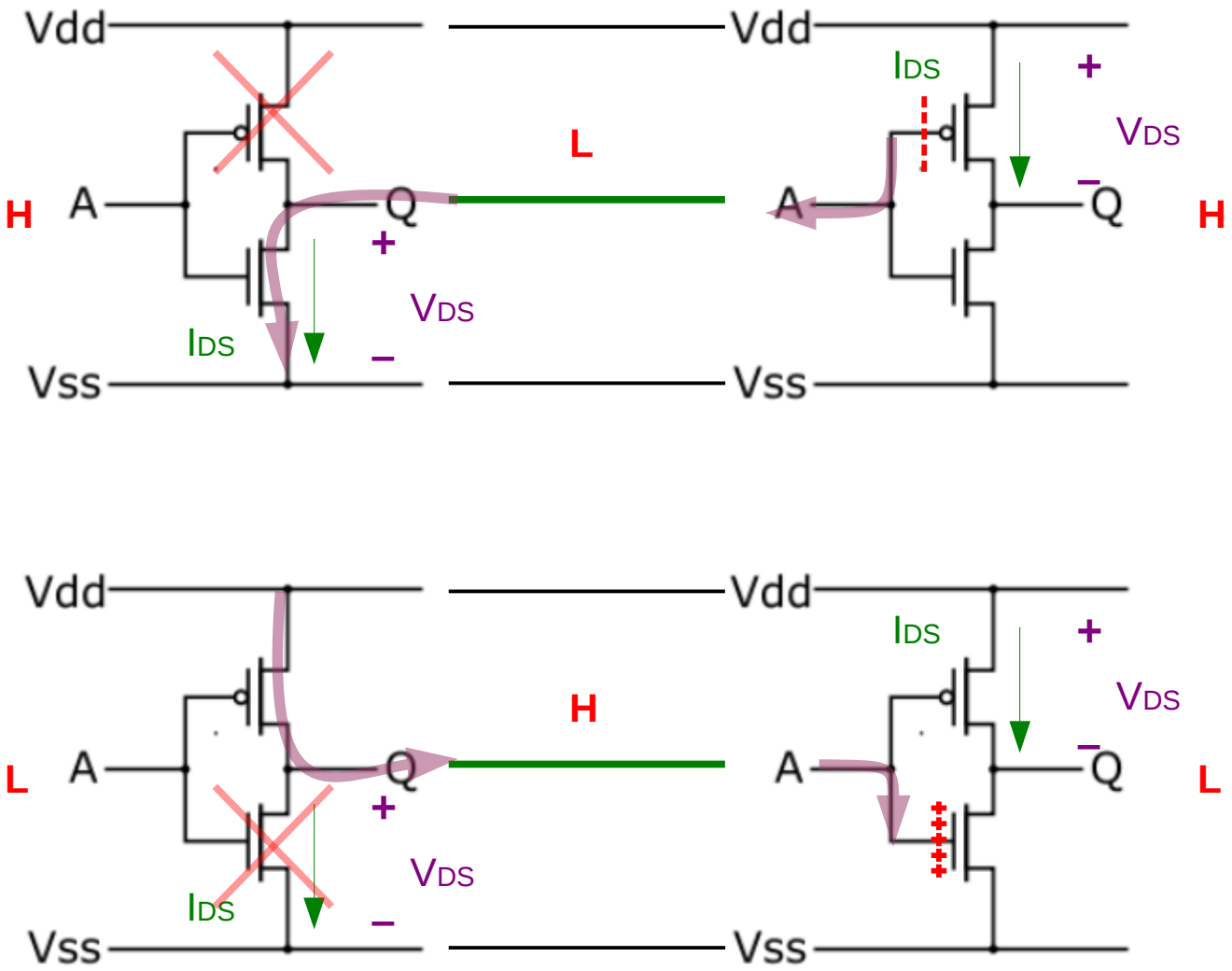


# Characteristic Curves (2)

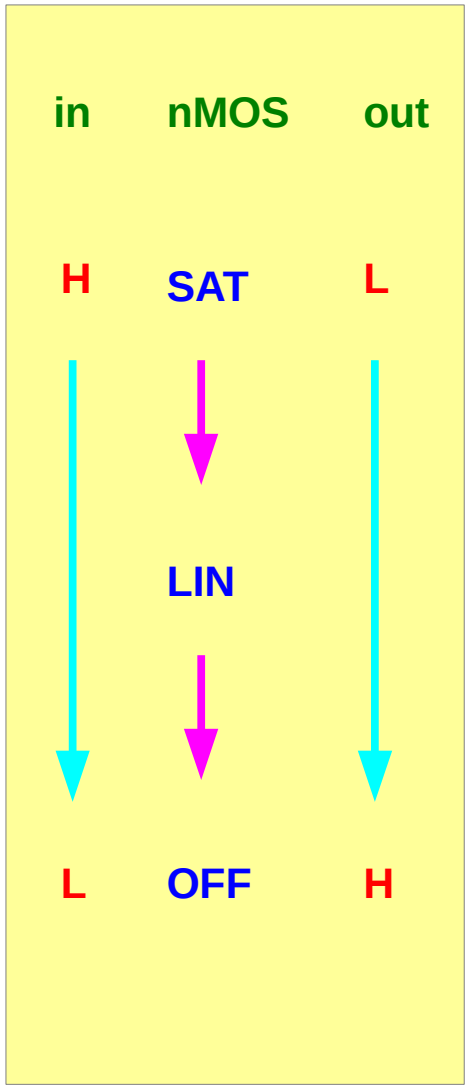


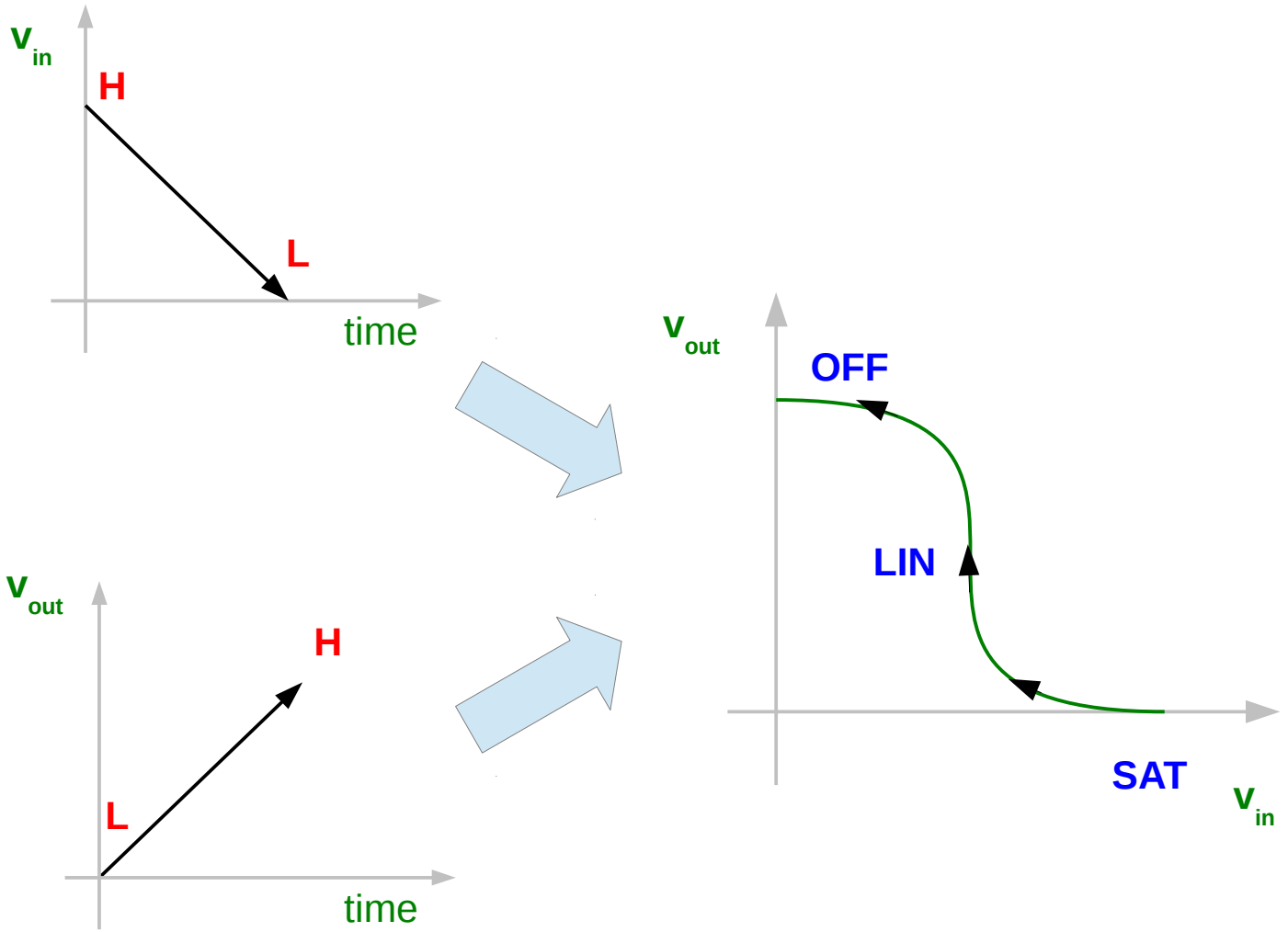
# Voltage Transfer Curve (1)

| in | nMOS | out |
|---|---|---|
| H | SAT | L |
| | LIN | |
| L | OFF | H |

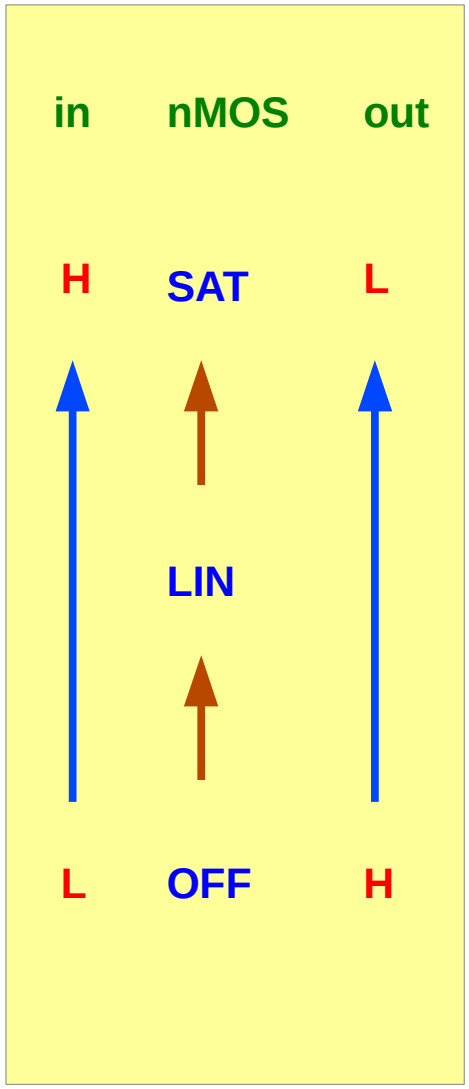


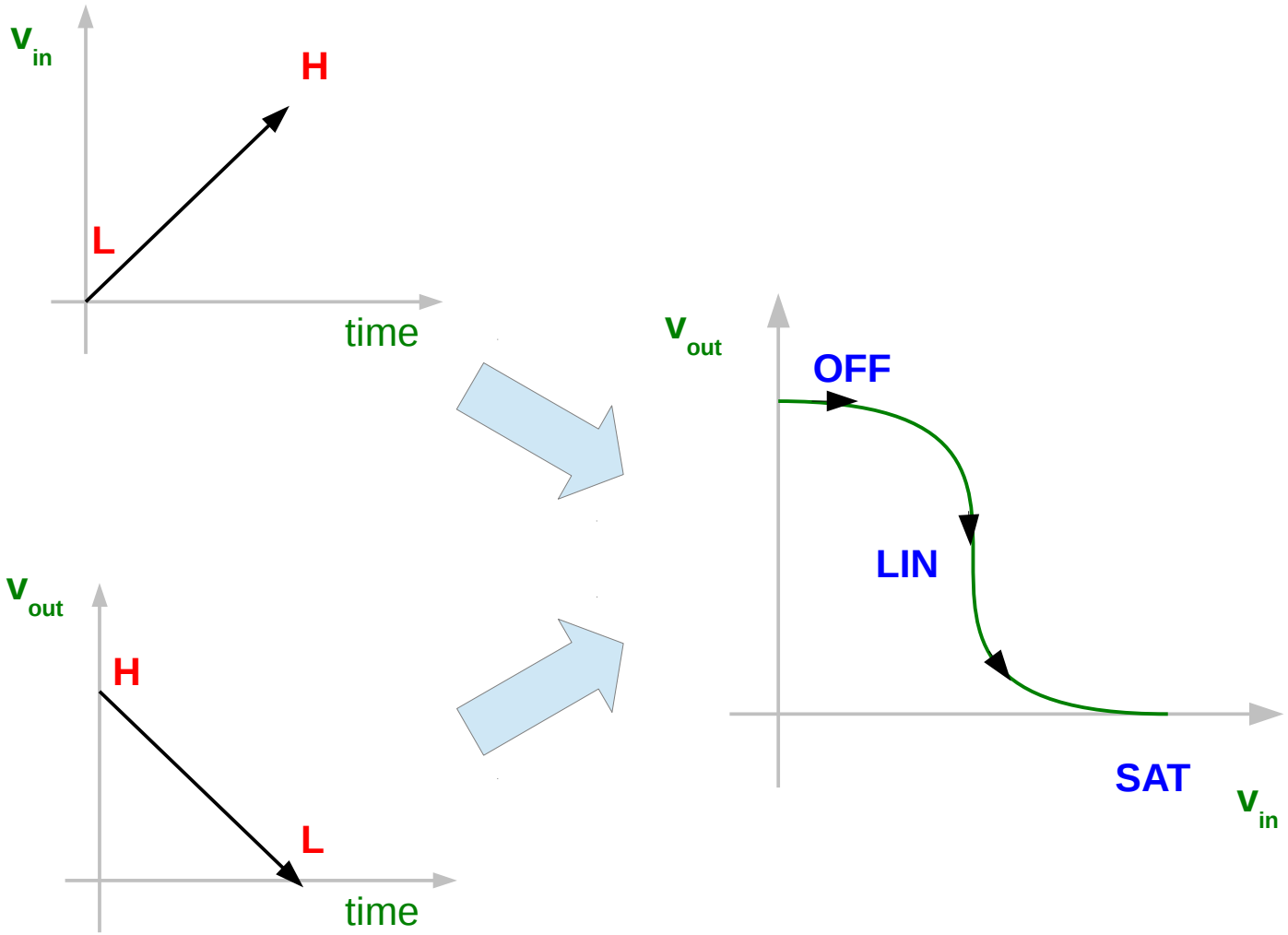
# Voltage Transfer Curve (2)



# Voltage Transfer Curve (2)



## References


[1] http://en.wikipedia.org/
[2] http://www.allaboutcircuits.com/
[3] W. Wolf, “Modern VLSI Design : Systems on Silicon
[4] N. Weste, D. Harris, “CMOS VLSI Design: A Circuits and Systems Perspective”