SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

19ECB302–VLSI DESIGN

III YEAR/ V SEMESTER

UNIT 1 –MOS TRANSISTOR PRINCIPLE

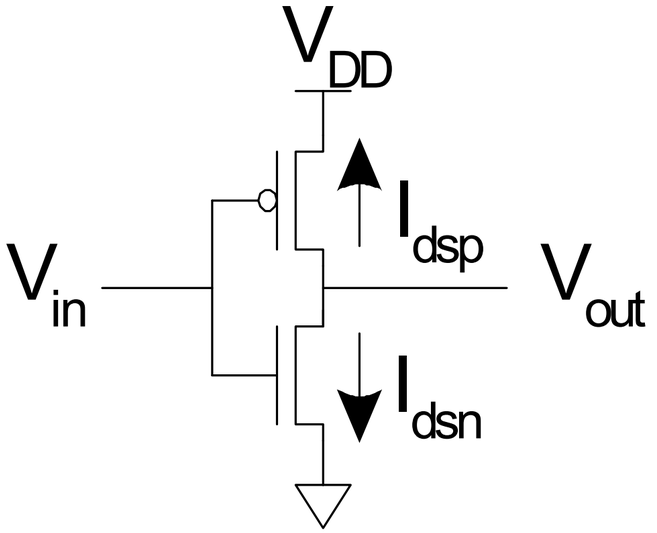
TOPIC 7 –CMOS INVERETER DC CHARACTERISTICS

OUTLINE

- INTRODUCTION
- DC RESPONSE
- LOGIC LEVELS AND NOISE MARGINS
- ACTIVITY
- TRANSIENT RESPONSE
- ASSESSMENT
- SUMMARY

DC RESPONSE

- DC Response: V_{out} vs. V_{in} for a gate
- Ex: Inverter
  - When $V_{in} = 0$ -> $V_{out} = V_{DD}$
  - When $V_{in} = V_{DD}$ -> $V_{out} = 0$
  - In between, V_{out} depends on transistor size and current
  - By KCL, must settle such that $I_{dsn} = |I_{dsp}|$
  - We could solve equations
  - But graphical solution gives more insight



TRANSISTOR OPERATION

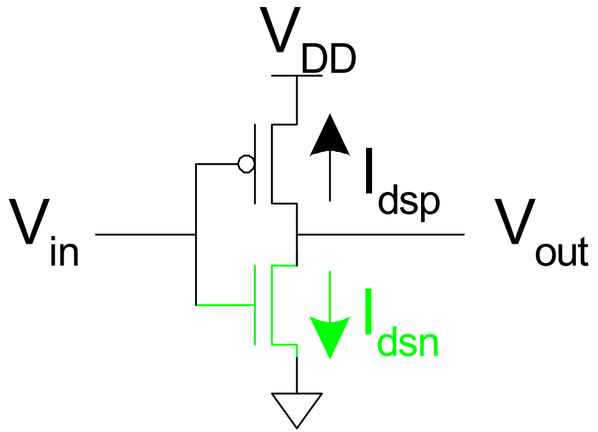
- Current depends on region of transistor behavior
- For what V_{in} and V_{out} are nMOS and pMOS in
  - Cutoff?
  - Linear?
  - Saturation?

NMOS OPERATION

Cutoff	Linear	Saturated
$V_{gsn} < V_{tn}$	$V_{gsn} > V_{tn}$	$V_{gsn} > V_{tn}$
$V_{in} < V_{tn}$	$V_{in} > V_{tn}$	$V_{in} > V_{tn}$
	$V_{dsn} < V_{gsn} - V_{tn}$	$V_{dsn} > V_{gsn} - V_{tn}$
	$V_{out} < V_{in} - V_{tn}$	$V_{out} > V_{in} - V_{tn}$

$$V_{gsn} = V_{in}$$

$$V_{dsn} = V_{out}$$



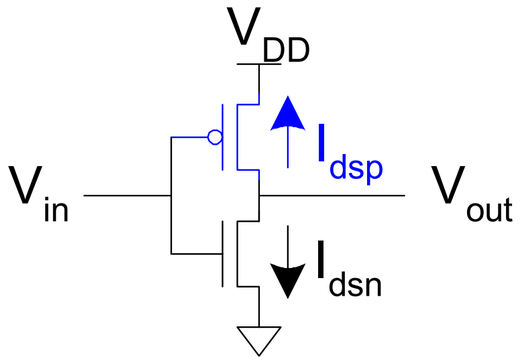
PMOS OPERATION

Cutoff	Linear	Saturated
$V_{gsp} > V_{tp}$ $V_{in} > V_{DD} + V_{tp}$	$V_{gsp} < V_{tp}$ $V_{in} < V_{DD} + V_{tp}$ $V_{dsp} > V_{gsp} - V_{tp}$ $V_{out} > V_{in} - V_{tp}$	$V_{gsp} < V_{tp}$ $V_{in} < V_{DD} + V_{tp}$ $V_{dsp} < V_{gsp} - V_{tp}$ $V_{out} < V_{in} - V_{tp}$

$$V_{gsp} = V_{in} - V_{DD}$$

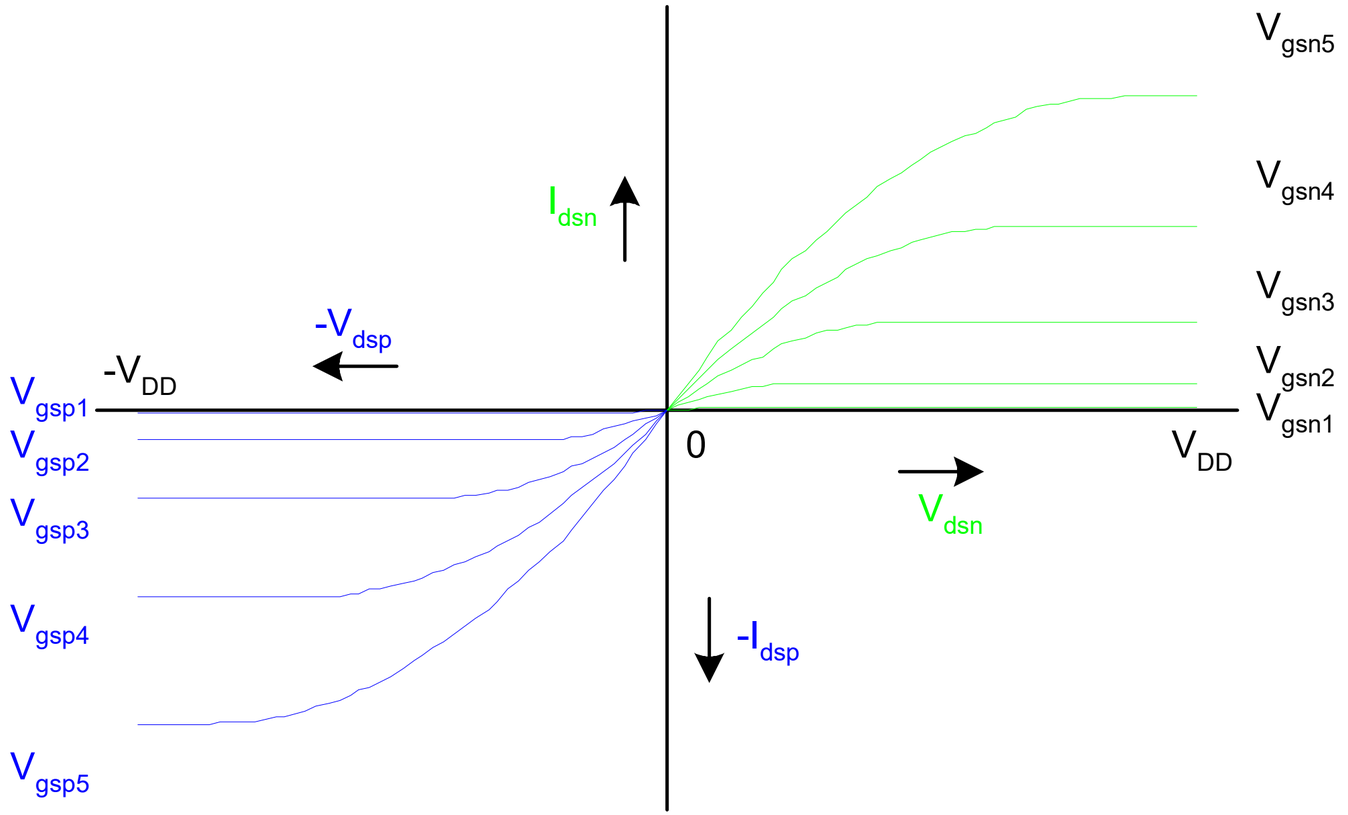
$$V_{dsp} = V_{out} - V_{DD}$$

$$V_{tp} < 0$$

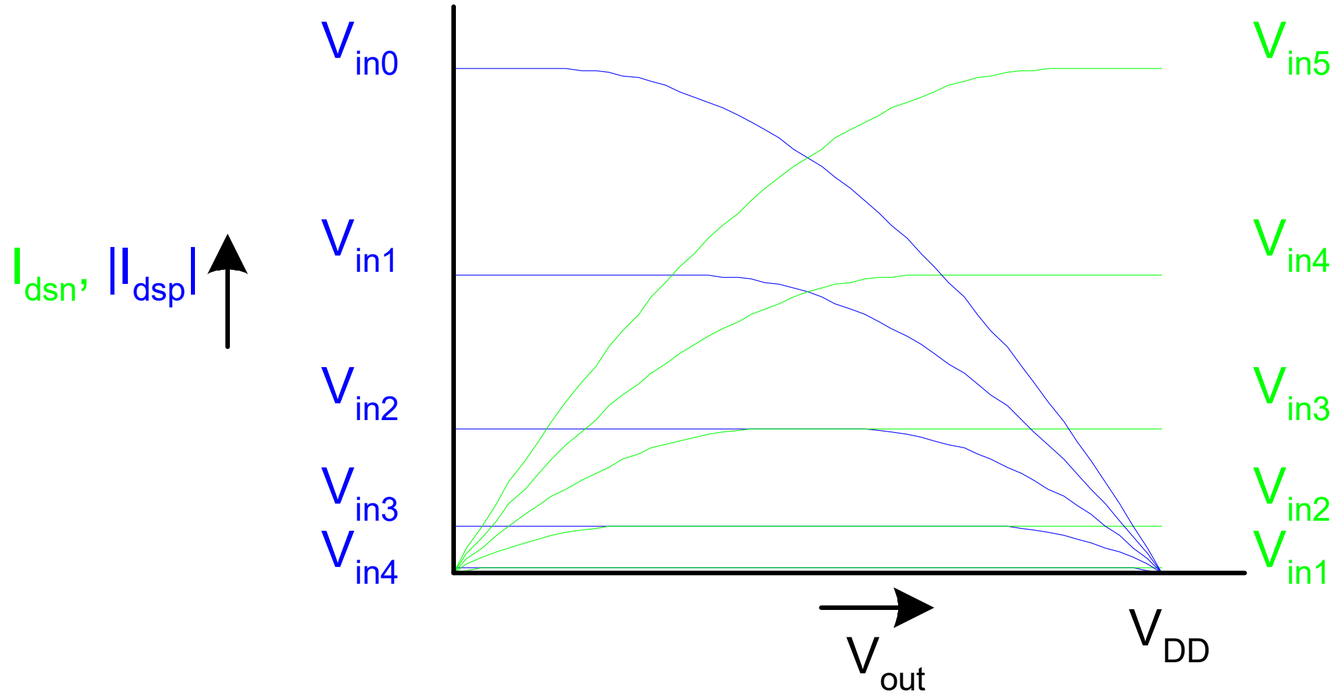


I-V CHARACTERISTICS

Make pMOS is wider than nMOS such that $\beta_n = \beta_p$

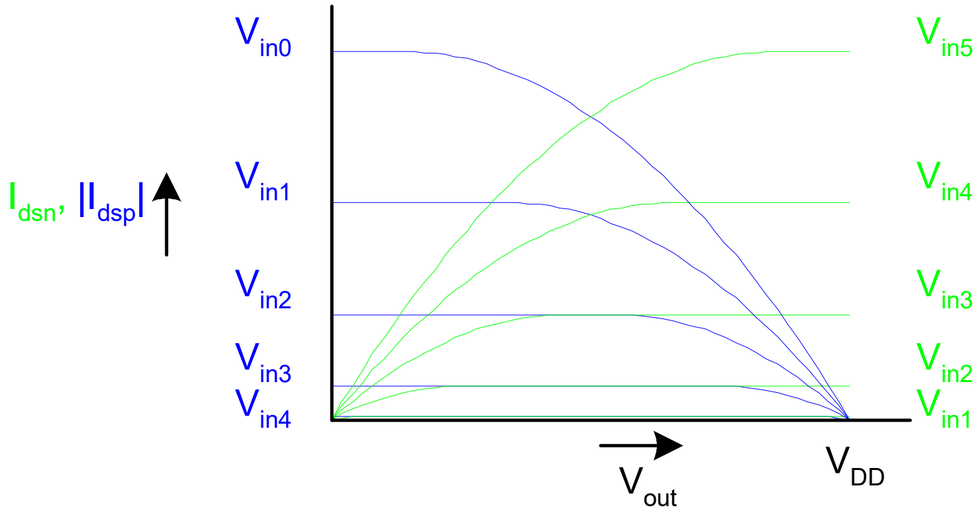


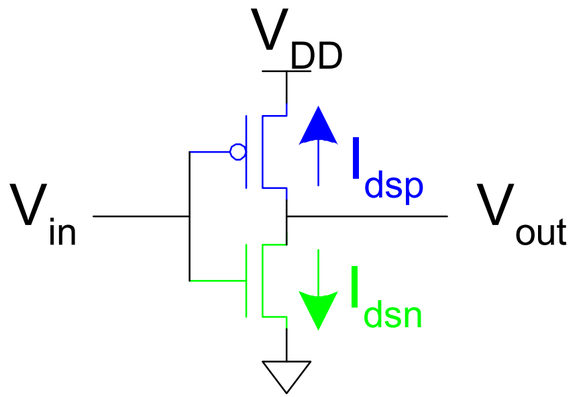
CURRENT VS V_{OUT} , V_{IN}



LOAD LINE ANALYSIS

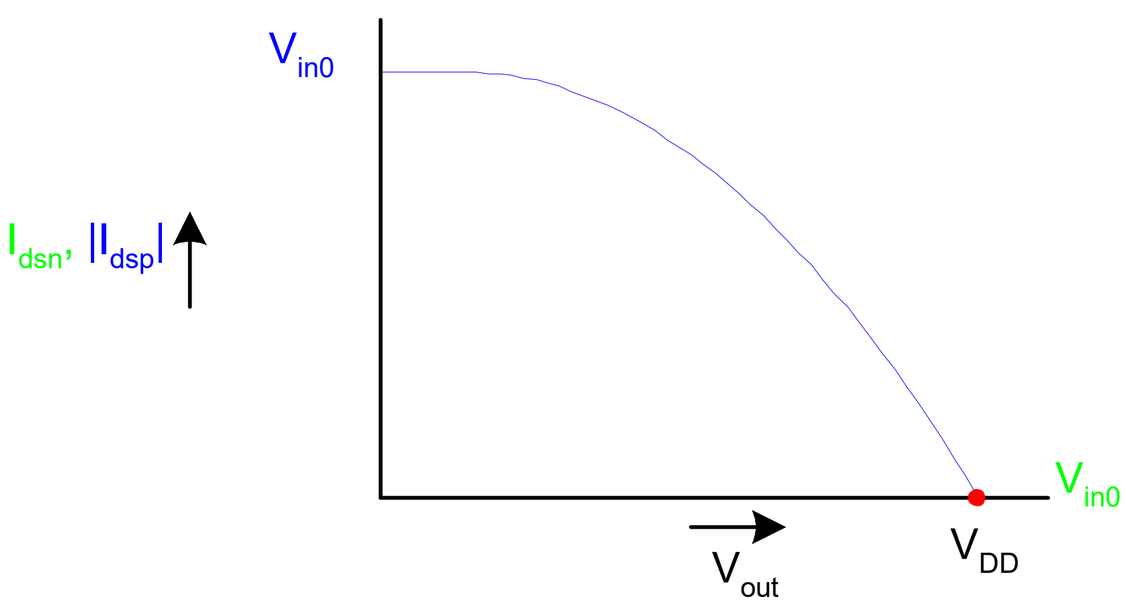
- For a given V_{in}:
  - Plot I_{dsn}, I_{dsp} vs. V_{out}
  - V_{out} must be where |currents| are equal in



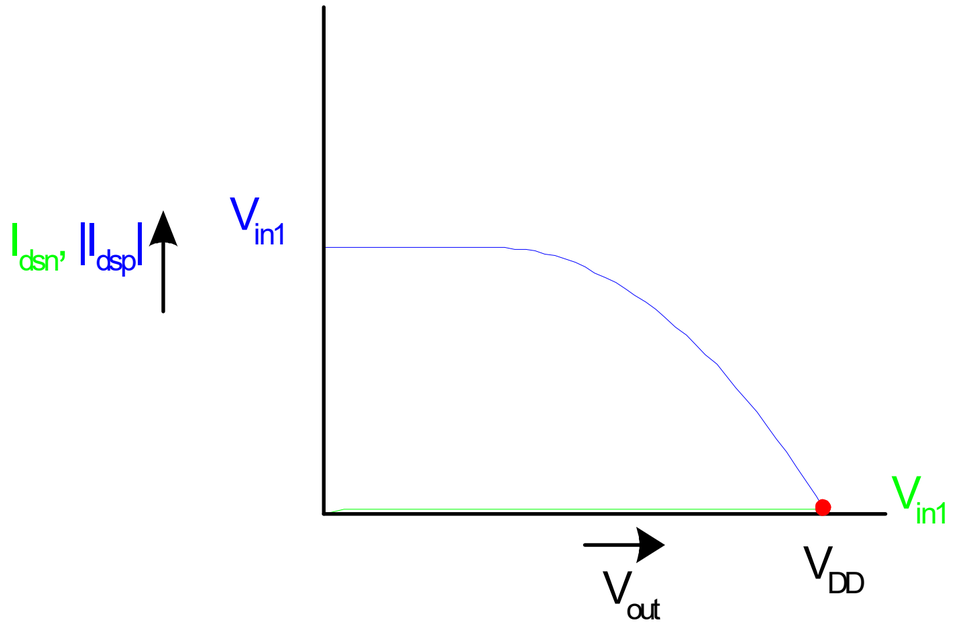


LOAD LINE ANALYSIS

$V_{in} = 0$



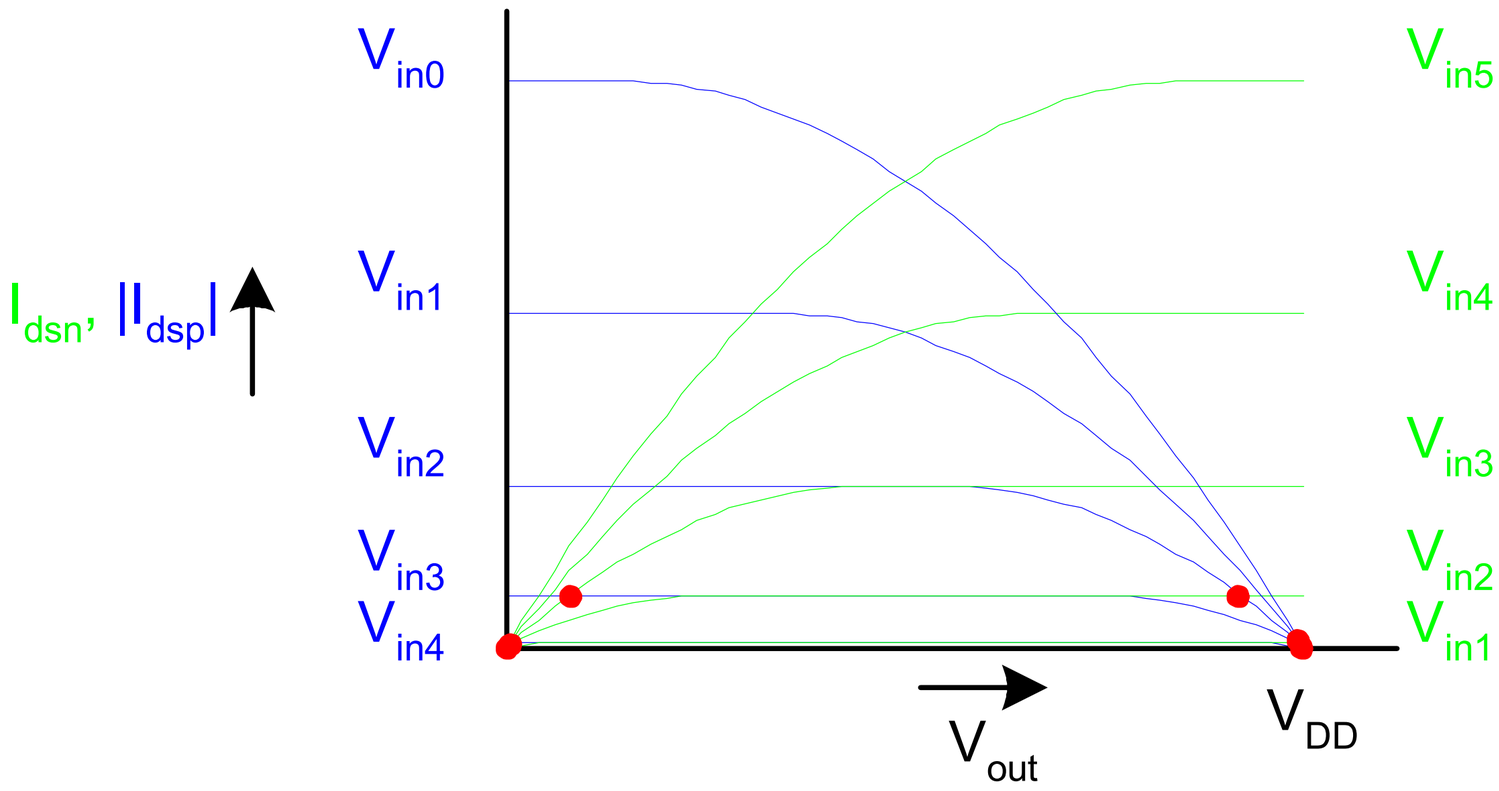
$V_{in} = 0.2V_{DD}$



ACTIVITY-BRAIN TEASERS

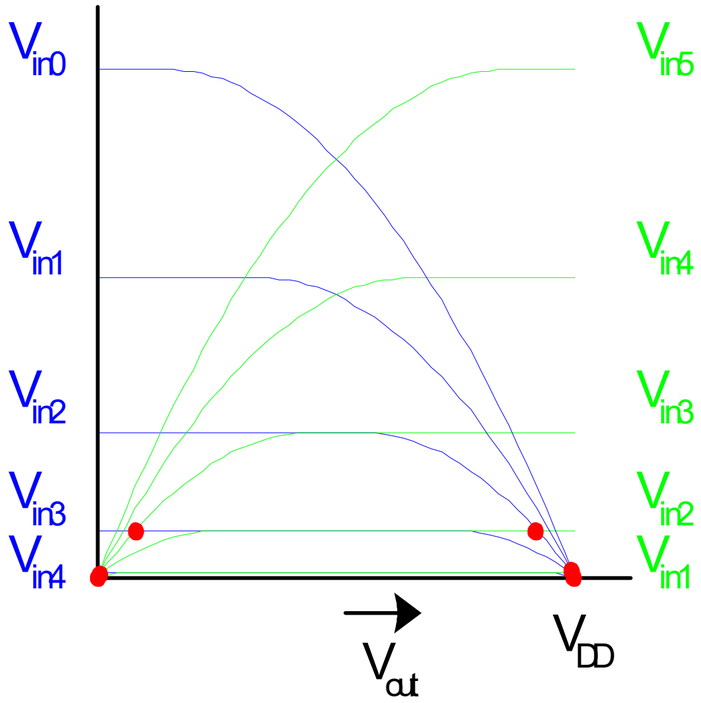
1	2 FUSS	3	4 TIK
5 o L D	6 TILL IME	7 JOB AN	8 W O R L
9 P P O D	10 INITIA__	11 FILE	12 JUS 144 TICE
13 WOHNICLEE	14 L O V	15 1 T 3 4 5 6	16 BRING BALLERINAS

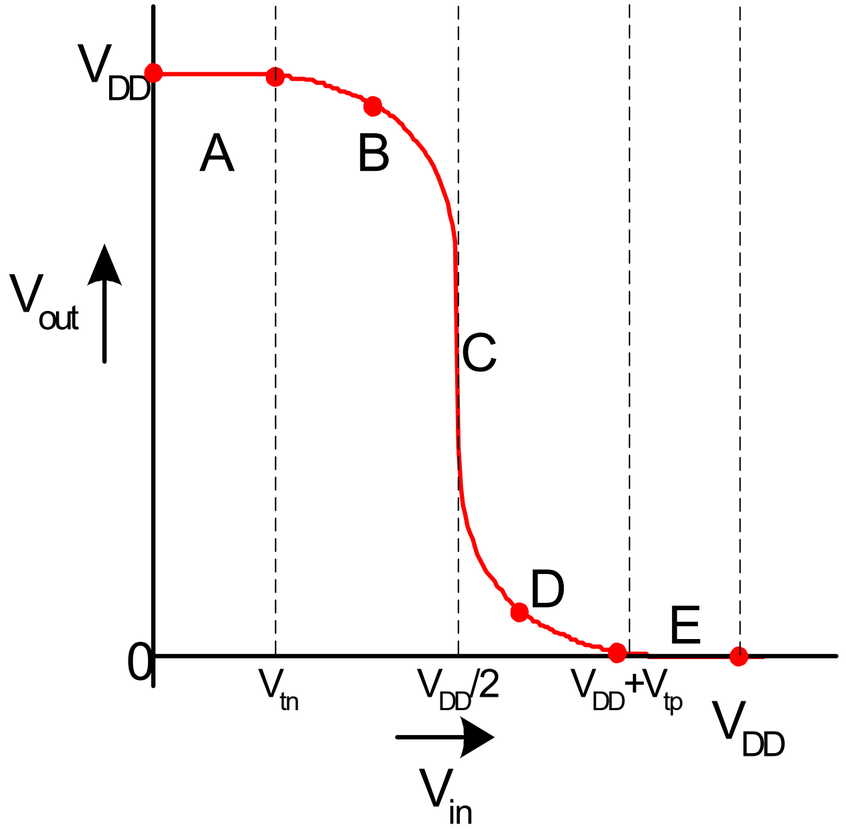
LOAD LINE ANALYSIS SUMMARY



DC TRANSFER CURVE

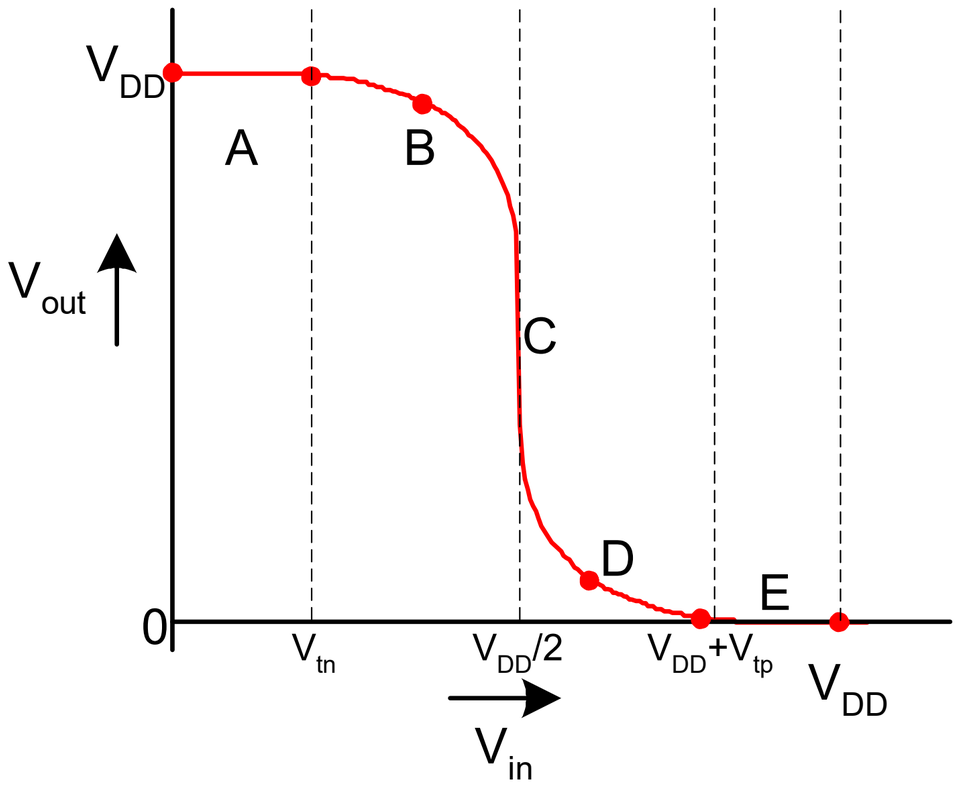
Transcribe points onto V_{in} vs. V_{out} plot





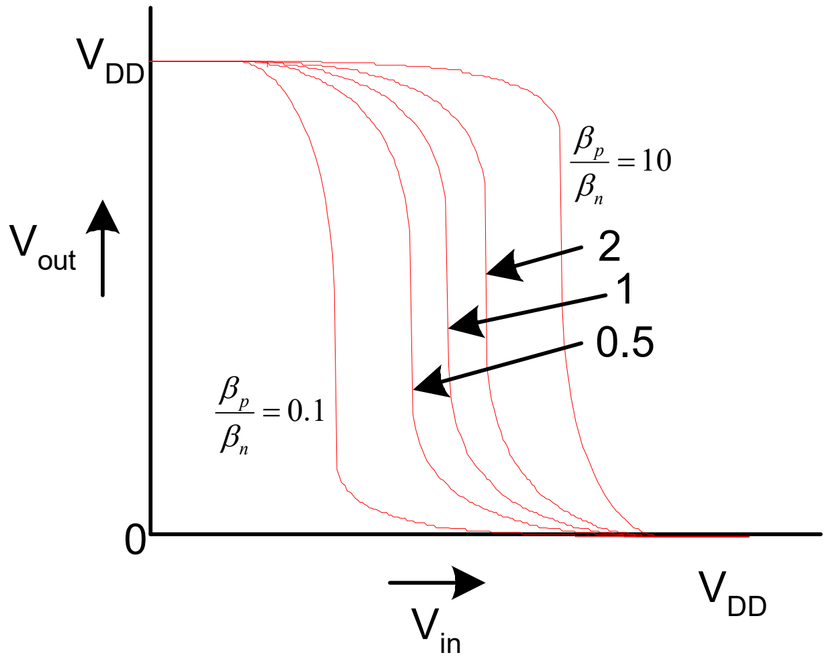
REVISIT TRANSISTOR OPERATING REGIONS

Region	nMOS	pMOS
A	Cutoff	Linear
B	Saturation	Linear
C	Saturation	Saturation
D	Linear	Saturation
E	Linear	Cutoff



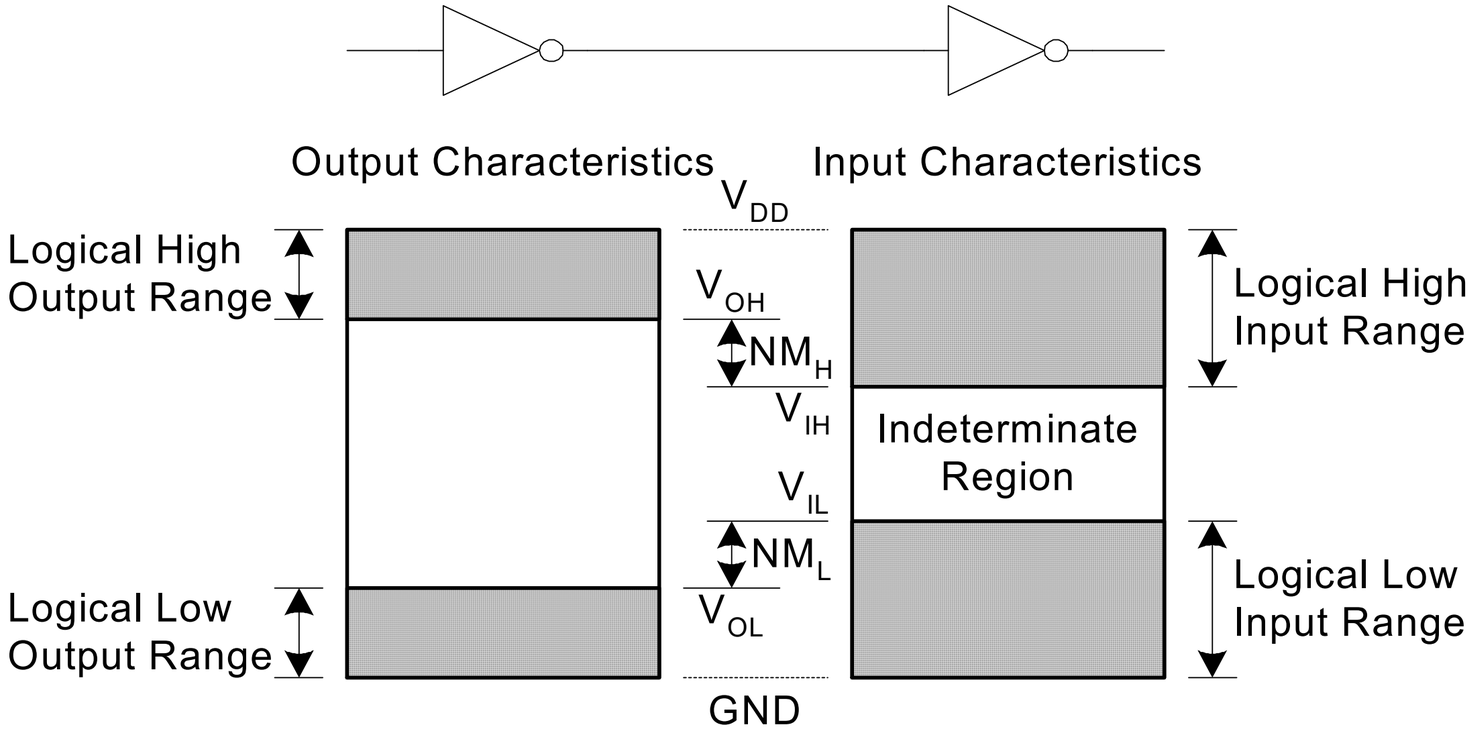
BETA RATIO

If $\beta_p / \beta_n \neq 1$, switching point will move from $V_{DD}/2$ Called skewed gate
Other gates: collapse into equivalent inverter



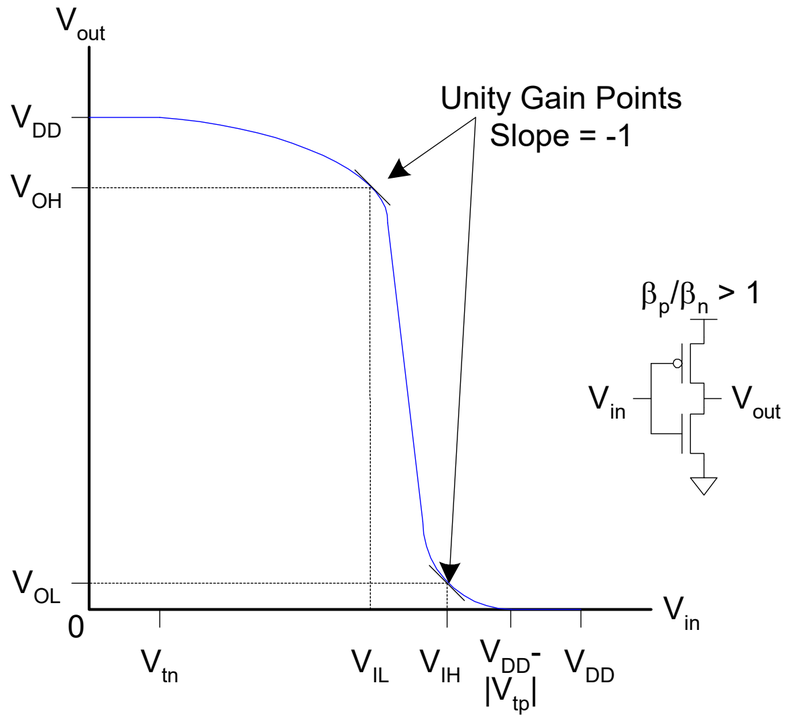
NOISE MARGINS

How much noise can a gate input see before it does not recognize the input?



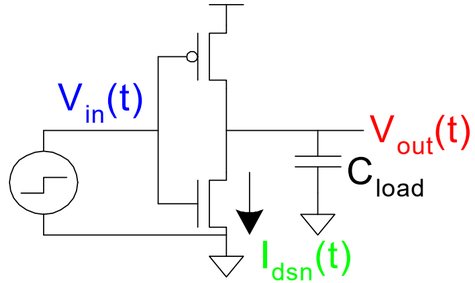
LOGIC LEVELS

To maximize noise margins, select logic levels at unity gain point of DC transfer characteristic



TRANSIENT RESPONSE

- DC analysis tells us V_{out} if V_{in} is constant
- Transient analysis tells us $V_{out}(t)$ if $V_{in}(t)$ changes
  - Requires solving differential equations
- Input is usually considered to be a step or ramp
  - From 0 to V_{DD} or vice versa

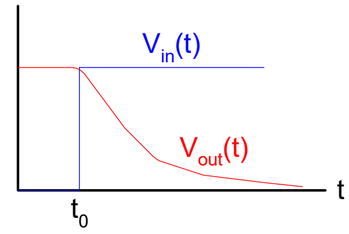


$$V_{in}(t) = u(t - t_0)V_{DD}$$

$$V_{out}(t < t_0) = V_{DD}$$

$$\frac{dV_{out}(t)}{dt} = -\frac{I_{dsn}(t)}{C_{load}}$$

$$I_{dsn}(t) = \begin{cases} 0 & t \le t_0 \\ \frac{\beta}{2}(V_{DD} - V)^2 & V_{at} > V_{DD} - V_t \\ \beta\left(V_{DD} - V_t - V_{at}(t)/2\right)V_{at}(t) & V_{at} < V_{DD} - V_t \end{cases}$$



ASSESSMENT

1) If the width of a transistor increases, the current will

increase decrease not change

2) If the length of a transistor increases, the current will

increase decrease not change

3) If the supply voltage of a chip increases, the maximum transistor current will

increase decrease not change

4) If the width of a transistor increases, its gate capacitance will

increase decrease not change

5) If the length of a transistor increases, its gate capacitance will

increase decrease not change

6) If the supply voltage of a chip increases, the gate capacitance of each transistor will

increase decrease not change

ACTIVITY

1) If the width of a transistor increases, the current will

increase decrease not change

2) If the length of a transistor increases, the current will

increase **decrease** not change

3)If the supply voltage of a chip increases, the maximum transistor current will

increase decrease not change

4) If the width of a transistor increases, its gate capacitance will

increase decrease not change

5) If the length of a transistor increases, its gate capacitance will

increase decrease not change

6) If the supply voltage of a chip increases, the gate capacitance of each transistor will

increase decrease **not change**

SUMMARY & THANK YOU