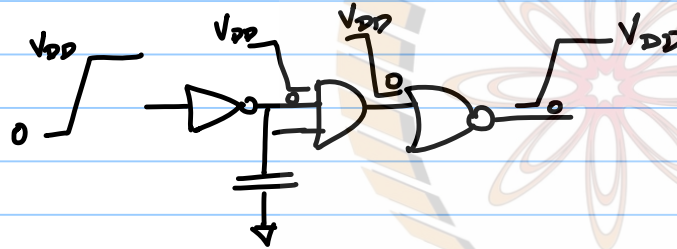


26/08/2019

EES311

MODULE - 3 - THE INVERTER



CHARGING / DISCHARGING A CAPACITANCE

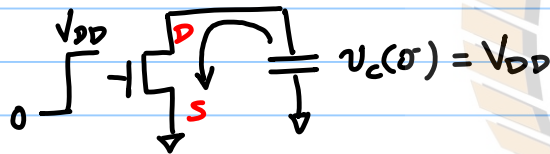
NMOS  
PMOS

CH  
DIS

NPTEL

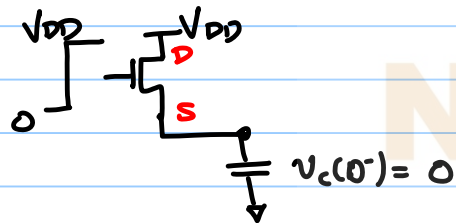
NMOS: DRAIN  $\rightarrow$  SOURCE CURRENT FLOW  
(IDEAL  $\Rightarrow$  NO LEAKAGE)

DISCHARGING



$$V_{GS}(t) = V_{DD} > V_T \quad \forall t$$

CHARGING:



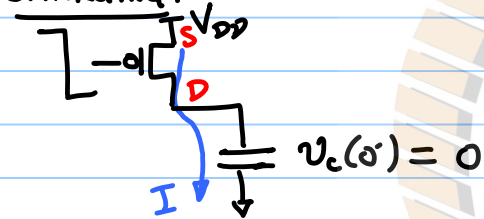
$$V_{GS}(t) = V_{DD} - V_c(t) > V_T$$

$$V_c(t) < V_{DD} - V_T \quad (\text{MAX VALUE THAT AN NMOS CAN PASS})$$

★ VERY SLOW CHARGING

PMOS : S  $\rightarrow$  D CURRENT FLOW

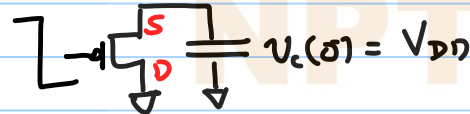
CHARGING:



$$V_{gs}(t) = -V_{DD} < V_{Tp}$$

CAP CAN CHARGE TO  $V_{DD}$

DISCHARGING:



$$V_{gs}(t) = -V_c(t) < V_{Tp}$$

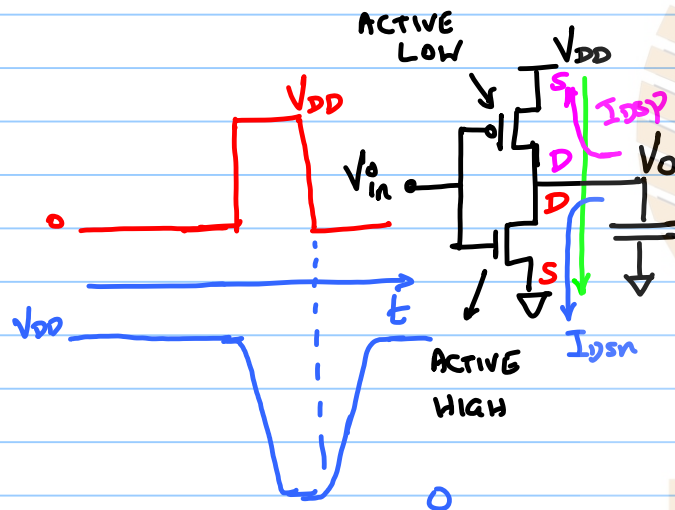
$$\text{OR } V_c(t) > |V_{Tp}|$$

$\Rightarrow$  PMOS CAN PASS ONLY UNTIL  $|V_{Tp}|$

NMOS : DISCHARGING

PMOS: CHARGING

### CMOS GATE (INVERTER)



NMOS  
PMOS

$V_{as}$	$V_{ds}$
$V_{in}$	$V_o$
$V_{in} - V_{DD}$	$V_o - V_{DD}$

$$I_{dsn} = -I_{dsp} \quad \forall t$$

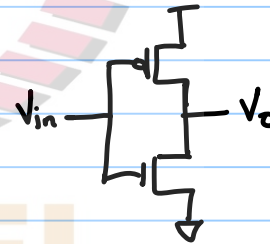
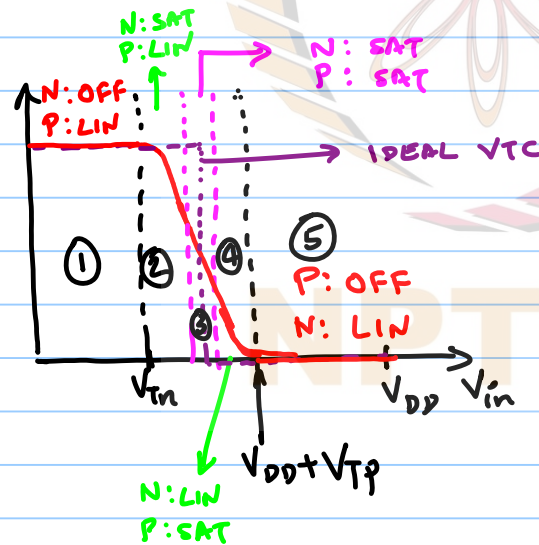
If  $V_{in} = 0 \Rightarrow V_{asn} = 0 (< V_{tn})$   
 $\Rightarrow I_{dsn} = 0 \Rightarrow I_{dsp} = 0$

$\Rightarrow V_{dsp} = 0 \Rightarrow V_o - V_{DD} = 0$   
 $\therefore V_o = V_{DD}$

If  $V_{in} = V_{DD} \Rightarrow V_{asp} = V_{in} - V_{DD} = 0 (> V_{Tp})$   
 $\Rightarrow I_{Dsp} = 0 \Rightarrow I_{Dsn} = 0$   
 $\therefore V_{Dsn} = 0 \Rightarrow V_o = 0$

### VOLTAGE TRANSFER CHAR (VTC)

1) NMOS TURNS ON IN  $V_o$  SATURATION (PMOS: LIN)



$V_{asn} = V_{in} \quad V_{asp} = V_{in} - V_{DD}$   
 $V_{dsn} = V_o \quad V_{dsp} = V_o - V_{DD}$   
 $I_{Dsn} = -I_{Dsp}$

$V_{asp} < V_{Tp}$   
 $\Rightarrow V_{in} - V_{DD} < V_{Tp}$   
 $\Rightarrow V_{in} < V_{DD} + V_{Tp}$