DC characteristics of MoS transistor

- A complementary CMOS inverter consists of a p-type and an n-type device connected in series.
- The DC transfer characteristics of the inverter are a function of the output voltage (Vout) with respect to the input voltage (Vin).

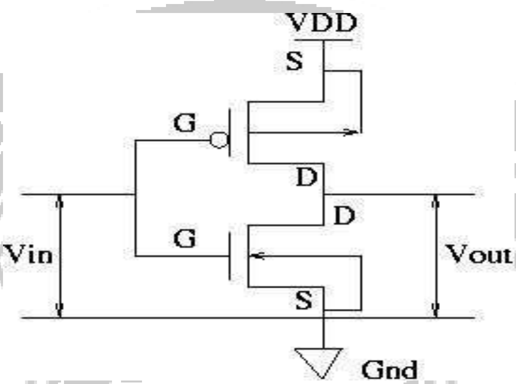

Fig 1.4.1MOS Transistor

[Source: Neil H.E. Weste, CMOS VLSI Design …]

- The MOS device first order Shockley equations describing the transistors in cut-off, linear and saturation modes can be used to generate the transfer characteristics of a CMOS inverter.
- Plotting these equations for both the n- and p-type devices produces the traces below.

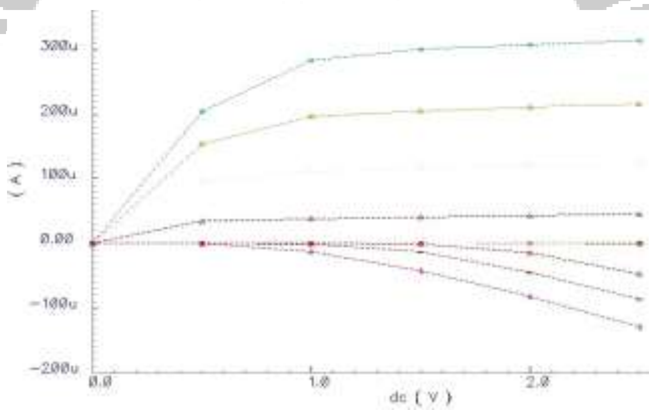

Fig 1.4.2 MOS Transistor IV Characteristics

[Source: Neil H.E. Weste, CMOS VLSI Design …]

- The DC transfer characteristic curve is determined by plotting the common points of Vgs intersection after taking the absolute value of the p-device IV curves, reflecting them about the x-axis and superimposing them on the n-device IV curves.
- We basically solve for Vin(n-type) = Vin(p-type) and Ids(n-type)=Ids(p-type)
- The desired switching point must be designed to be 50 % of magnitude of the supply voltage i.e. VDD/2.
- Analysis of the superimposed n-type and p-type IV curves results in five regions in which the inverter operates.

- **Region A** occurs when 0 leqVin leq Vt(n-type).
  - The n-device is in cut-off (Idsn =0).
  - p-device is in linear region,
  - Idsn = 0 therefore -Idsp = 0
  - Vdsp = Vout – VDD, but Vdsp =0 leading to an output of Vout = VDD.
- **Region B** occurs when the condition Vtn leq Vin le VDD/2 is met.
  - Here p-device is in its non-saturated region Vds neq 0.
  - n-device is in saturation

Saturation current Idsn is obtained by setting Vgs = Vin resulting in the equation:

- In **region B** Idsp is governed by voltages

Vgs and Vds described by:

- Saturation currents for the two devices are:
- **Region D** is defined by the inequality
- p-device is in saturation while n-device is in its non-saturation region.

- Equating the drain currents allows us to solve for Vout. (See supplemental notes for algebraic manipulations).
- In **Region E** the input condition satisfies:
- The p-type device is in cut-off: Idsp=0
- The n-type device is in linear mode
- Vgsp = Vin –VDD and this is a more positive value compared to Vtp.
- Vout = 0