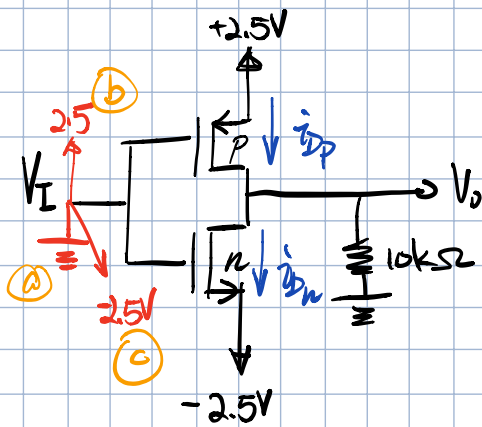


#### Example 4 CMOS Circuit.



$$V_{th} = |V_{tp}| = 1V$$

$$k_n' \left(\frac{W}{L}\right)_n = k_p' \left(\frac{W}{L}\right)_p = 1 \text{ mA/V}^2$$

find  $i_{Dn}$  &  $i_{Dp}$  and  $V_O$  for

$$V_I = 0V, +2.5V, -2.5V$$

(a)

(b)

(c)

(a)  $V_{GS_n} = 0V - (-2.5V) = 2.5V > V_{th} \therefore$  transistor (n-type) on.

$V_{SG_p} = 2.5V - (0V) = 2.5V > |V_{tp}| \therefore$  transistor (p-type) on.

$\rightarrow$  both p & n conducting.

$i_{Dp} = i_{Dn}$  ( $\because$  they are matched (all parameters are the same) &  $|V_{GS}|$  are the same)

$\Rightarrow V_O = 0V$  (drain volt. for both trans.)

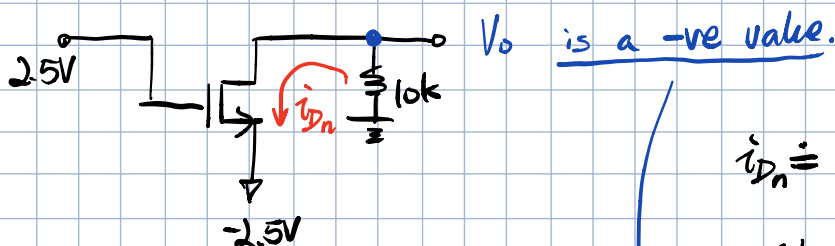
both transistor are in saturation.

$$I_{Dp} = I_{Dn} = \frac{1}{2} k_n' \left(\frac{W}{L}\right)_n V_{OV}^2 = \frac{1}{2} \times (1 \text{ mA/V}^2) (V_{GS} - V_{th})^2$$

$$= 1.125 \text{ mA}$$

(b)

$V_{SG} = 2.5 - 2.5 = 0V < |V_{tp}| \therefore$  p-type is turned off.



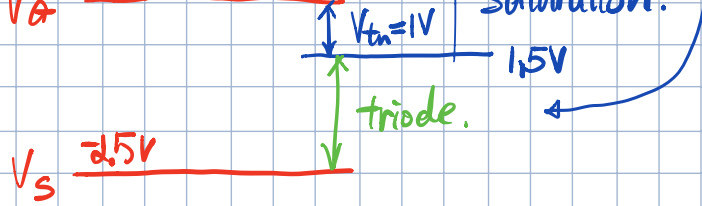
$$i_{Dn} = k_n' \left(\frac{W}{L}\right) V_{OV} V_{DS}$$

$$= (1 \text{ mA/V}^2) (V_{GS} - V_{th}) (V_O - (-2.5V))$$

$$= 1 (5 - 1) (-0.01 + 2.5)$$

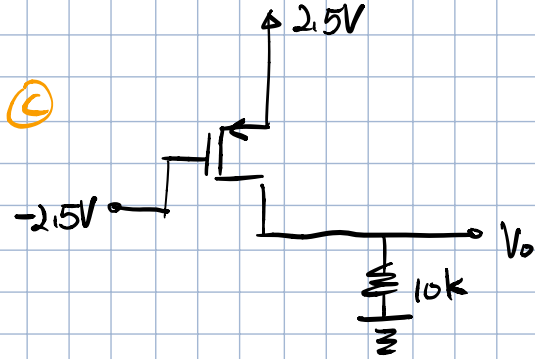
$V_{GS} = 2.5V$

saturation



$$i_{Dn} = 0.244 \text{ mA}$$

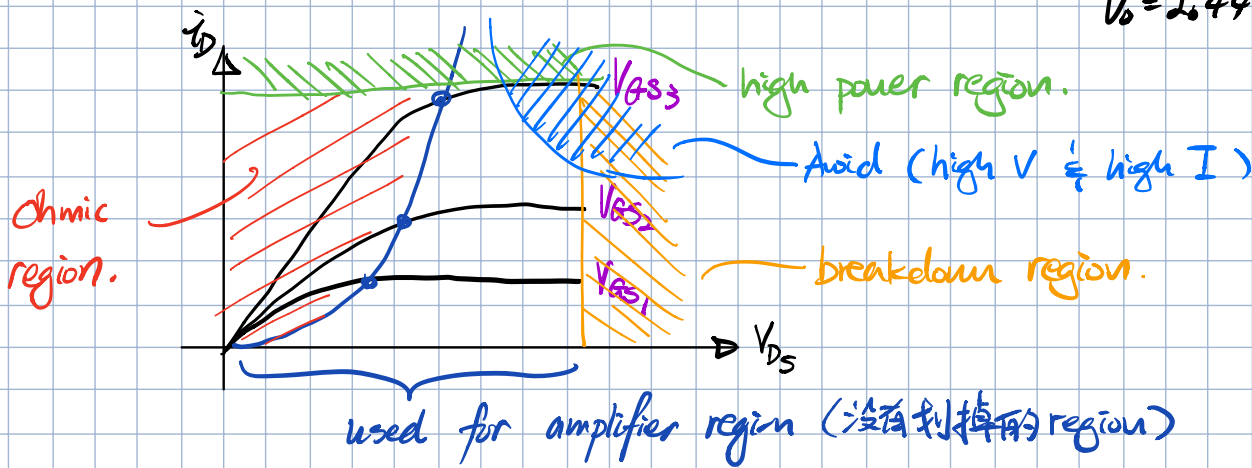
$$V_o = -2.44 \text{ V}$$



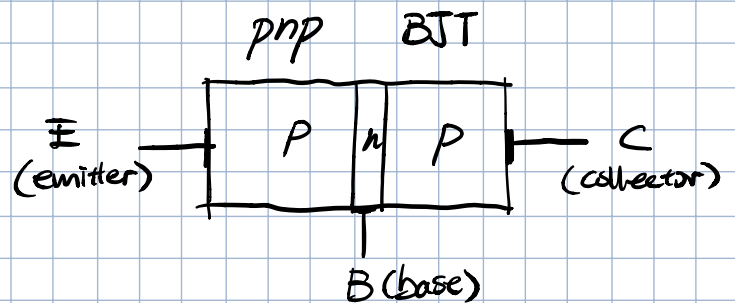
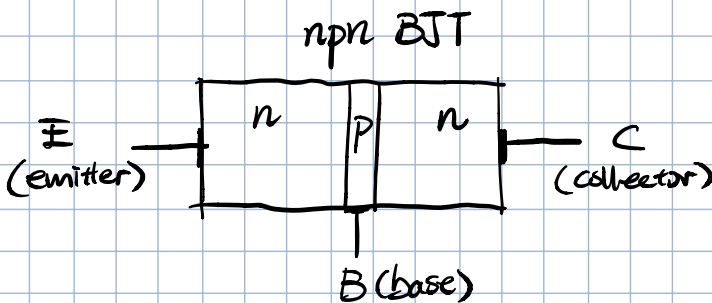
n-type is turned off, while p-type is conducting in triode region.

$$i_{Dp} = k_p' \left( \frac{W}{L} \right)_p |V_{ov}| |V_{sp}| \quad i_{Dp} = 0.244 \text{ mA}$$

$$V_o = 2.44 \text{ V}$$



## BJT IV characteristics.

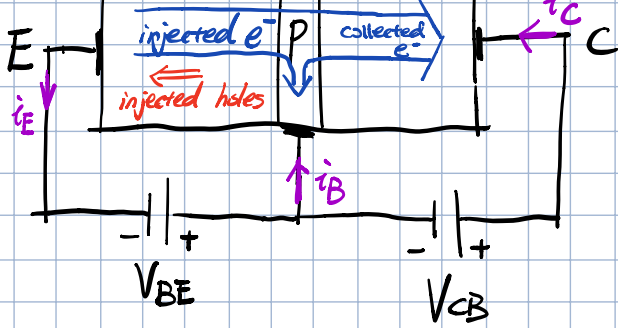


## BJT in active mode

(emitter base junction)  $\Rightarrow$  forward biased.

CBJ (collector base junction)  $\Rightarrow$  reversed biased.





$i_E$ 

- injected  $e^-$
- injected holes

$i_C < \text{collected } e^-$

$$i_C = I_S e^{V_{BE}/V_T}$$

thermal voltage (25mV)  $\swarrow$   $V_{BE}/V_T$   
 base to emitter voltage  $\nwarrow$

$\propto$  FBJ area  
 $\propto \frac{1}{\text{base width}}$

scale current  $\swarrow$   
 $(10^{-12} \text{ to } 10^{-8} \text{ A})$